

Research Landscape of Diabetes mHealth Technologies

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Abstract

In recent years, more and more generic technologies have appeared, allowing one to find answers simultaneously along different dimensions, “fan” solutions for urgent and complex problems are synthesized and cumulative effects emerge. This article analyzes the potential of such technologies using the example of mobile health (mHealth), which provides rapid access to medical services even in the most remote regions, mitigating the inequalities between different segments of the population in this regard. The implementation of mobile health becomes especially important in the context of the rapid spread of chronic and

autoimmune diseases, which strongly impact the quality and duration of life. Smart applications based on AI and virtual reality provide the opportunity to manage one’s health by combining patient self-monitoring with rapid consultations with medical staff. By doing so, risks are reduced and physiological and mental well-being is enhanced. This article conducts a large-scale literature review of diabetes management techniques through mobile technology to systematize and identify the most advanced solutions. For such innovations to maximize their impact, public health policies must be aligned with a digitalization strategy.

Keywords: generic technologies; mHealth; health innovation; chronic disease management; diabetes; health services; health self-management; health policy; digitalization strategy

Citation: Castillo-Valdez P.F., Rodriguez-Salvador M., Ho Y.S. (2024) Research Landscape of Diabetes mHealth Technologies. *Foresight and STI Governance*, 18(1), pp. 19–32. DOI: 10.17323/2500-2597.2024.1.19.32

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Introduction

The constant development of digital technologies has created many opportunities in the field of digitalization by enabling the integration of physical and digital activities. Many sectors, especially healthcare, are devoting important efforts to accelerate digitalization (Leung et al., 2017). Digital healthcare integrates digital information, health services, and patient care to facilitate activities such as care delivery, patient documentation, prescriptions, interventions, and health monitoring (Sharma et al., 2018). Preventive medicine options are expanding, treatment is becoming more personalized and reaching all segments of the population, including in remote areas (Ronquillo et al., 2022). Emerging technologies can help patients improve their health conditions (Williams et al., 2019) and provide personalized care plans. This offers the opportunity to empower patients by enabling them to learn and manage their diseases (Ding et al., 2019).

mHealth is a term commonly used in the health sector concerning the use of mobile technology to improve health conditions, providing benefits such as reducing costs, facilitating monitoring activities, and encouraging self-management activities and healthy lifestyles (Kumar et al., 2013). mHealth can facilitate the healthcare delivery by removing barriers related to geographic location (Nahum-Shani et al., 2016) and time, as consultations, interventions, and medical care can be provided remotely at any moment (Stoyanov et al., 2015). Mobile technologies such as wearable devices, smartphones, sensors, and mobile apps offer new opportunities to improve health. mHealth has a significant impact on chronic disease management. For example, thanks to strong connection of people to their smartphones (Hamine et al., 2015) and the apps available, it is possible to help control obesity, heart disease, and diabetes, among others (Silva et al., 2015).

Research in this area is particularly relevant given the projected increase in the dynamics of diabetes. According to data for 2021, its global prevalence among adults aged 20-79 years was 9.3% (about 463 million people). By 2045, 783.2 million people in this age group (12.2%) are projected to have diabetes. Thus, the number of patients will increase by 25% from current levels by 2030 and by 51% by 2045. As for global health expenditures for this type of disease, in 2021 they were estimated at \$966 billion, and by 2045 the amount will be \$1,054 billion (IDE, 2021).

Diabetes mHealth research is evolving rapidly. Diverse studies have embraced the application and development of mobile technology to improve disease control, monitoring, treatment plans, interventions, and lifestyle behavior changes to assist in the daily management of this disease. However, no research has explored the dynamics of the scientific progress of Diabetes mHealth to identify research topics in the field, which is crucial to make better decisions regarding Research, Development (R&D), and Innovation. The aim of our study is to fulfill the gap. The results of this review can inform the planning of public health policy. We have identified relevant research topics, the support of which will increase the effectiveness of innovation in this area.

Methodology

The word distribution analysis involves a set of scientific literature documents and their word partition of their article titles, author keywords, and keywords plus¹ to reveal the main research topics (Wang, Ho, 2016). Identifying research topics within this field can facilitate researchers, academics, industry, decision-makers, and policymakers to prioritize their R&D efforts, and have a panorama for future research directions. For this purpose, the SCI-Expanded database was used, which is a prestigious scientific collection that includes over 9,500 journals, 182 subject categories, and covers up to 61 million records from Clarivate Analytics². The dataset was obtained after the publication of the Journal Impact Factor 2021, which was reported in the Journal Citation Report (JCR)³, and the period from 1998 to 2021 was considered.

A search strategy was created accordingly focused on article-type documents. Relevant diabetes-related terms were incorporated into the search strategy and those related to mobile technologies. In addition, exclusion terms were included to avoid documents that contained key terms but were related to other topics, such as genetics, proteins, mobile health as a physical unit, wearables with no mobile or wireless capabilities, and others. The keywords used are displayed in a Venn diagram as shown in Figure 1. These keywords were incorporated into a search query using quotation marks and Boolean operators that are displayed in the same figure. This search query was executed on SCI-Expanded using the Topic option, which includes searching by title, abstract, author keywords, and Keywords Plus.

From 1998 to 2021, a total of 1848 articles were obtained. To strengthen the certainty of the results, Ho's group developed a "front page" filter that was applied in this study to reduce irrelevant articles (Wang, Ho, 2011). This resulted in 1668 articles that represented 90% of the original 1848 articles. Further manual analysis was conducted obtaining 1574 articles on Diabetes mHealth research.

In general, the article title, author keywords, and Keywords Plus in SCI-Expanded convey the most important information about the research. Words from these article sections provide readers with the relevant details of a topic and the main author's expressions (Mao et al., 2010; Fu et al., 2013). Manual codification was performed to identify words from the title, author keywords, and keyword plus of the 1574 retrieved documents. Stop words such as prepositions, conjunctions, pronouns, articles, etc. were removed as they were irrelevant to the analysis.

In the case of the title, the phrases were divided into single words to perform their statistical analysis. The title contains significant information with details that an author uses to denote the relevance of the topic discussed, becoming the initial view of the reader. This information contributes to identifying the focus and emphasis that authors disseminate. A total of 3467 words were found in the article titles after removing stop words. Table A1 (see Appendix) shows the top 50 most frequent single substantive words considering the number of articles in which the word appears in the title, its

¹ Keywords Plus from Web of Science offers additional search terms formulated using words and phrases extracted from the cited paper titles by the authors (Mao et al., 2010).

² <https://clarivate.com/products/scientific-and-academic-research/research-discovery-and-workflow-solutions/web-of-science/web-of-science-core-collection/science-citation-index-expanded/>, accessed 05.04.2023.

³ <https://clarivate.com/blog/the-2021-journal-citation-reports-a-continuing-evolution-in-journal-intelligence/>, accessed 05.07.2022.

ranking according to the number of articles containing the word in the 1574 retrieved documents.

In the authors' keywords, the phrases were kept intact, in contrast to the title where the phrases were split into single words. Author keywords provide information that can reveal scientific directions and research trends, which is useful for the continuous monitoring of science and technology (Mao et al., 2010). After excluding stop words, a total of 3274 author keywords were identified. However, only 419 of them appeared in three or more articles. This means that 2523 keywords appeared in only one article and 332 keywords appeared in two articles, probably indicating different research foci and discontinuity in topics. Table A1 shows the top 50 most frequent author keywords according to their rank considering the number of articles in which the term appears and its percentage relative to the total number of articles.

Similarly, for Keyword Plus, phrases were retained intact as they were provided. In addition, the development of a Keyword Plus statistical analysis allows for more detail and insight into advances in Diabetes mHealth by comparing similar and dissimilar trends in author keywords. A total of 2287 Keywords Plus were identified. Table A1 shows the top 50 most frequent Keyword Plus considering their rank, the number of articles containing them, and their corresponding percentage in relation to the total number of articles.

After the statistical word analysis in article titles, author keywords, and Keywords Plus, the word distribution analysis was performed to detect similar phrases or common single words and generate supporting words, which contain the resulting terms integrated. The word distribution analysis provides relevant clues, subjective focus, and emphasis of research based on supporting words to determine a research topic, in this case on Diabetes mHealth. The use of supporting words can overcome the possible weakness of the separate analysis of statistical word distribution in article titles, author keywords, and Keywords Plus (Mao et al., 2010; Fu et al., 2013; Wang, Ho, 2016).

To determine supporting words, only terms that appeared in three or more articles in either titles, author keywords, or Keywords Plus were considered. A total of 1876 terms met this criterion (939 from titles, 419 from author keywords, and 516 from Keywords Plus). These terms were grouped as supporting words by manual inspection to finally identify the most relevant research topics. Certain terms were discarded by their broad meaning, while others, although broad, were matched into the research topic that made them most meaningful. Finally, each research topic and its supporting words were validated by incorporating feedback from experts. The results are presented in the next section.

Results and Discussion

The word distribution analysis allowed to determine research topics and their respective ranking as a result of the supporting words. A total of 141 research topics were identified which were grouped into the following six categories: 1) Health problems, 2) Technologies, 3) Applications, 4) Global perspectives, 5) Population groups, and 6) Healthcare professionals. Table 1 contains a general description of the content of these topics while the Table 2 lists the keywords that define research topics in these categories. The top three categories with more research topics were "Health problems", "Technologies", and "Applications" with 31, 29, and 27 research topics, respectively. A detailed overview of the research topics included in each of these top three categories

along with their supporting words is provided below.

Each article in the set of scientific documents can contribute to more than one research topic. For example, the article entitled "Impact of Daily Physical Activity as Measured by Commonly Available Wearables on Mealtime Glucose Control in Type 1 Diabetes" contributes to category 1 "Health problems" in the topic of Type 1 diabetes mellitus, as well as to category 2 "Technologies" in the topic Wearable, and in category 3 "Applications", in the research topics of Glucose handling, Physical activity, and Food intake.

Category 1. Health problems

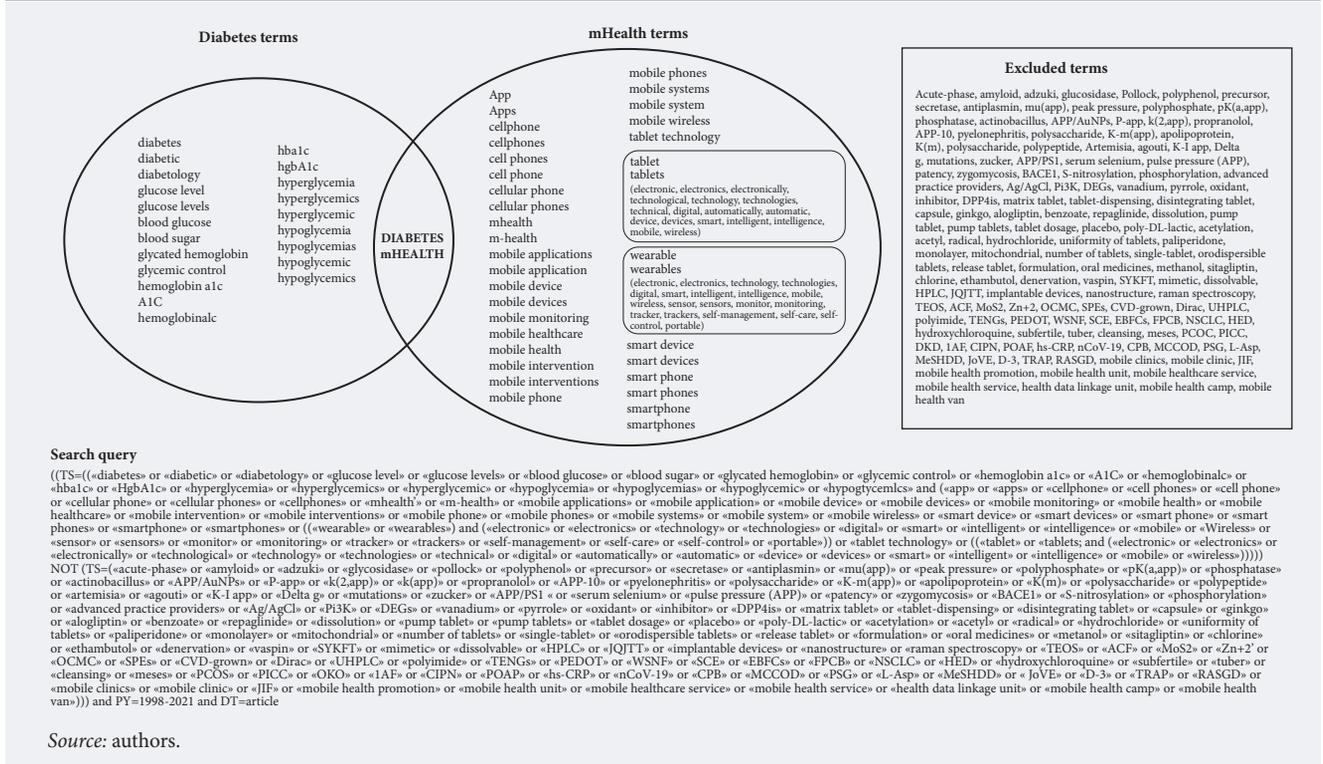
This category contains research topics where mHealth has been contributing to diabetes health problems, including diseases, complications, risk factors, and medical conditions. Four sub-categories were identified as follows: diseases, diabetic complications, risk factors, and complications. **Table A2** lists the research topics identified in this category by rank and subcategory.

The sub-categories diseases, diabetic complications, risk factors, and complications consider 13, 7, 8, and 3 research topics respectively, a total of 31 research topics in this category. Type 2 Diabetes mellitus, gestational diabetes mellitus, cardiovascular diseases, type 1 diabetes mellitus, and chronic diseases are the top five research topics in the "diseases" sub-category. Diabetic retinopathy and diabetic foot are the top two topics in the "diabetic complications" sub-category, while obesity is the top topic in the "risk factor" sub-category. Figure 2 displays a graph of the topics mentioned previously with the number of articles that contain their supporting words in the title, author keywords and keyword plus, distributed by year of publication. This graph shows the main research focus and the development trends in the branch of health problems.

Diabetes mellitus occurs when the body does not produce the insulin it needs, preventing adequate control of blood glucose levels. It has several classifications, each with a different pattern and treatment, the most common being type 1, type 2, and gestational diabetes. The research topic of "type 2 diabetes mellitus" refers to a type of diabetes mellitus in which the body does not produce enough insulin or is resistant to insulin, so it is not possible to properly regulate the level of glucose in the blood. This can cause risks in the organism, especially in the eyes, heart, feet, nerves, and kidneys. To cope with it, it is important to make lifestyle changes such as diet and exercise habits, take medications properly, and undergo regular medical examinations. In our analysis 324 articles were related to this topic. Recent advances in digital platforms and their evaluation, as well as text messaging strategies through social media apps and Short Message Service (SMS), have seen remarkable development. Li et al. (2021) uncovered that mHealth management for patients with type 2 diabetes has better cost-effectiveness characteristics than conventional care mode. Instant messaging social networking app can be beneficial to increase the knowledge on self-care activities and to improve intervention programs in patients with type 2 diabetes (Alanzi et al., 2018; Middleton et al., 2021).

The research topic of "type 1 diabetes mellitus" covers a type of diabetes mellitus in which the pancreas produces very little or no insulin due to the loss of insulin-producing beta cells in the pancreas as a result of a genetic condition that manifests itself at an early age. Therefore, lifelong insulin administration, continuous glucose monitoring, carbohy-

Figure 1. Venn diagram of Diabetes mHealth terms and the resulting query



drate intake control, and exercise are required to reduce the risk of developing other complications. 185 articles are on this topic. Progress in food tracking algorithms, wearables, and artificial pancreases have enabled advances in the control and management of type 1 diabetes, improving patients' quality of life. Alfonsi et al. (2020) demonstrate the feasibility of a mobile app for carbohydrate counting based on food image recognition through machine learning to support young people with diabetes mellitus type 1. Al Hayek and Al Dawish (2020) demonstrate the effectiveness of flash glucose monitoring to improve diabetes distress, glycemic levels, and sleep quality in young adults with type 1 diabetes mellitus. Ahmed et al. (2020) highlighted perspectives on the use of technologies related to do-it-yourself (DIY) artificial pancreas systems for young patients with diabetes mellitus type 1, which involves the use of open-source digital models to determine the delivery of insulin.

The research topic of “cardiovascular diseases” refers to health conditions that negatively affect the heart, blood vessels and arteries, causing damage to a variety of organs, including the brain, kidneys, eyes, and others. High blood sugar levels, sedentary lifestyle, and overweight are risk factors that can damage blood vessels. The number of articles related to this topic is 129. There have been important advances in the use of digital tools to improve education, behavior change, and control of cardiovascular disease. Ernsting et al. (2019) identified the need for digital literacy and behavior change techniques to improve the effective use of health apps in patients with cardiovascular disease, diabetes, or both. Nepper et al. (2019) revealed the effective use of a mobile phone text messaging program to improve cardiovascular disease education and promote risk awareness, healthy eating, and self-management activities. Cirilli et al. (2019) proved the feasibility of using a wearable to track physical activity to reduce cardiovascular risk factors that

persist in diabetes and identified novel microRNA biomarkers for future research.

The research topic of “chronic diseases” covers health conditions lasting one year or more that demand constant attention, changes in daily activities, behavioral limitations, etc. Diseases such as diabetes, cancer, asthma, and heart failure are considered chronic diseases. The number of articles related to this topic is 123. Some studies are beneficial not only for diabetes but also for other chronic diseases. Progress in the usefulness of mobile applications and digital environments for chronic diseases is highlighted. Abbasi et al. (2020) assessed the attitudes of patients with chronic diseases towards the use of mobile technologies and found that the attitudes of diabetic and multiple sclerosis patients were more positive compared to those of asthmatic patients. Omboni et al. (2021) determined the usefulness of a telehealth platform at scale for chronic disease management to identify deterioration in health status.

The research topic of “diabetic retinopathy” concerns complications related to the eyes in patients with diabetes. A total of 103 articles are linked to this topic. The potential impact of digital technology on the screening, control, and management of diabetic retinopathy has received much attention. Nunes et al. (2021) developed a mobile tele-ophthalmology system for primary care diabetic retinopathy screening that is easy to use by non-ophthalmology clinicians, reducing costs and helping to increase screening coverage. Malerbi et al. (2020) determined the feasibility of a smartphone-based portable retinal camera for diabetic retinopathy screening, useful for improving detection coverage. Jebaseeli et al. (2020) proposed an Internet of Things (IoT) framework for diabetic retinopathy diagnosis based on sensors, information sharing, and mobile applications that reached 99.58% accuracy.

The research topic of “obesity” focuses on a medical condition caused by excess body fat, which increases the risk of

Table 1. The general description of thematic categories

Category	Contents
Health problems	Diabetic complications and risk factors that mHealth technologies have made significant progress in addressing
Technologies	High-tech solutions that improve patient follow-up, patient self-management, communication between parties and therapeutic program development
Applications	Innovative mHealth software applications to address a variety of diabetic issues, changing the traditional ways of managing the course of the disease
Global perspectives	Prevalence of diabetic diseases, country-specific risk factors (dietary culture, lifestyle, etc.), preventive measures
Population groups	Demographic factors - age, gender, geography, etc.
Healthcare professionals	Development of professional competencies that contribute to the advancement of diabetes treatment methods
<i>Source:</i> authors.	

developing various health problems such as type 2 diabetes, heart disease, blood pressure, cholesterol, and others. Excess body fat can cause cells to become less sensitive to insulin, forcing the pancreas to produce more insulin to keep sugar levels under control, which can lead to insulin resistance and the development of type 2 diabetes. A total of 101 articles are related to this topic. There have been recent advances in the promotion of weight loss and intervention programs using apps, text messaging, and artificial intelligence. Several studies proved the effectiveness of a mobile lifestyle intervention to reduce body weight, glucose levels, and lipid metabolism in overweight or obese aged adults (Zhang et al., 2021; Stephens et al., 2019).

The research topic of “gestational diabetes mellitus” (GDM) refers to a type of diabetes mellitus in which there is a degree of glucose intolerance that is first identified during pregnancy, mainly due to hormonal changes. It requires control of food intake, pharmacological intervention, and constant monitoring during pregnancy. A total of 81 articles are associated with this topic. Valuable advances are highlighted in mobile applications that incorporate intelligent algorithms to improve the detection and control of gestational diabetes.

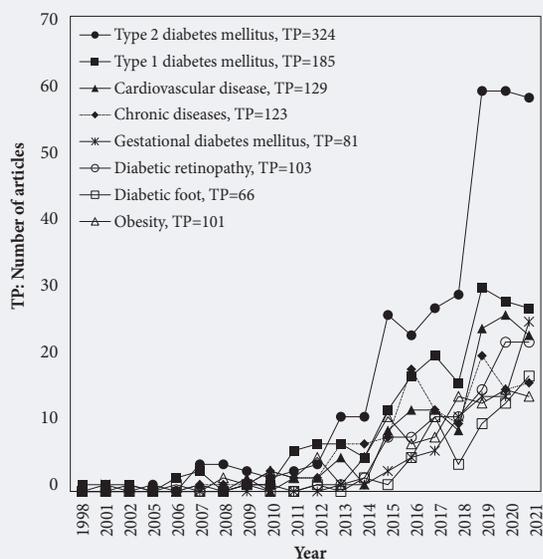
Some researchers validated the utility of a mobile application focused on restoring optimal weight in women with recent gestational diabetes mellitus to improve health habits and caloric intake through postpartum lifestyle interventions to reduce the risk of developing type 2 diabetes mellitus (Lim et al., 2021; Velardo et al., 2021)

Finally, the research topic of “diabetic foot” describes a variety of complications related to the region of the foot in patients with diabetes. In addition to damaging blood vessels, high blood glucose levels can damage nerves in the feet, resulting in loss of sensation, wound infections, ulcers, and possible amputation. Adequate blood sugar control, regular foot examinations, and appropriate footwear use can reduce diabetic foot complications. A total of 66 articles are related to this topic. Advances in smartphone cameras, machine learning models, and innovative smart devices such as insoles have been emphasized to implement monitoring and control programs for diabetic foot conditions. Wang et al. (2021) demonstrated the accuracy of a wireless footwear system including an insole for daily monitoring of plantar pressure in diabetic foot patients, providing real-time information via mobile phone for early detection of anomalies.

Table 2. Distribution of research topics by categories

Category	Keywords to describe research topics
Health problems	Type 2 Diabetes mellitus; Gestational diabetes mellitus; Cardiovascular disease; Type 1 diabetes mellitus; Chronic diseases; Coronary-heart-disease; Cancer; Non-communicable disease; Comorbid; Covid-19; Asthma; Chronic obstructive pulmonary disease; Multiple sclerosis; Diabetic retinopathy; Diabetic foot; Wound healing; Hypoglycemia; Diabetic peripheral neuropathy; Diabetic nephropathy; Ketoacidosis; Atrial fibrillation; Myocardial-infarction; Stroke; Obesity; Hypertension; Metabolic syndrome; Insulin resistance; Prediabetes; Hyperglycemia; Sedentary behavior; Smoking
Technologies	Smartphones; Mobile Apps; Sensors; Wearables; Text messaging; Machine learning; Internet; Artificial intelligence; Artificial pancreas; Medical devices; Big data; Internet of things (IoT); Biosensor; Smart contact lens; Web-based; Video games; Cloud computing; Fundus camera; Virtual reality; Calls; Tablet; Voice assistant; Blockchain; Electrocardiogram; Photoplethysmography; Glucometer; Infrared; thermography; Spectroscopy; 3D-Printing
Applications	Glucose handling; Interventions; Patient monitoring; Diabetes self-care; Physical activity; Healthcare delivery; Medication adherence; Diabetes education; Usability evaluation; Behavior change; Treatment; Patient examination; Healthy lifestyle; Decision-support-systems; Food-intake; Diabetes prevention; Personalized medicine; Insulin delivery-system; Mental health; Weight control; Patient empowerment; Electronic health record; Social support; Health promotion; Blood-pressure control; Diabetes management; Health policy
Global perspectives	Healthcare practice; Patients’ perspectives; Risk factors; Population; Prevalence; Primary care; Facilities; Mortality; Barriers; Public health; Pervasive healthcare; Survivors; Costs; Communities; Rural; Low-resource; Underserved; Urban; Socioeconomic; Developing countries; Digital divide; Ethnic-differences; Middle-income countries; Segmentation; Disability
Population groups	Adults; Adolescents; Children; Older adults; Youth; Women; Men; China; India; Africa; United States; Bangladesh; Latin America; Arabia Saudi; Norway; Asia; Pakistan; United Kingdom; Europa; Australia; Brazil; Canada; Peru; Taiwan
Healthcare professionals	Physician; Nurse; Pediatrician; Student; Specialist
<i>Source:</i> authors.	

Figure 2. The main research topics and their development trends in the health problems category



Note: Here and in subsequent figures, the number of articles containing auxiliary words in the title, author's author keywords, and Keywords Plus, distributed by year of publication, is shown.

Source: authors.

Category 2. Technologies

This category includes those topics that focus on the technologies needed to assist with diabetes issues. Technology provides solutions to support diabetes mellitus and the health problems associated with this disease by providing new tools and resources to improve the efficiency of diabetes management and control, including patient education and monitoring, intervention programs, and blood glucose control, among others. Table A3 displays the research topics identified in this category by rank.

Smartphones, mobile apps, sensors, wearables, text messaging, and machine learning are the top six research topics. Figure 3 presents a graph with the number of articles containing the supporting words of these top six topics in their title, author keywords, and keyword plus, distributed by year of publication. This graph displays the main emphasis of technologies research and its progression trends.

The research topic of “smartphones” (total number of articles on this subject is 494) highlights advances in the use of the smartphone camera as a mechanism for collecting data to be processed with machine learning algorithms, and the use of the flashlight as a mechanism for inducing actions. Jain et al. (2021) demonstrated the reliability of a smartphone-based fundus camera to capture ocular images to be processed by an offline artificial intelligence algorithm to detect diabetic retinopathy. Song et al. (2021) demonstrated the viability of a smartphone-based fluorescence microscope with a customizable optofluidic lens, and sensors to determine glucose levels, beneficial for facilitating timely detection of diabetes.

The research topic of “mobile apps” refers to software designed to run on mobile devices, such as smartphones, electronic tablets, and wearable devices, which provide a wide range of functions and services useful for healthcare services. There are 400 articles related to this topic. Notable

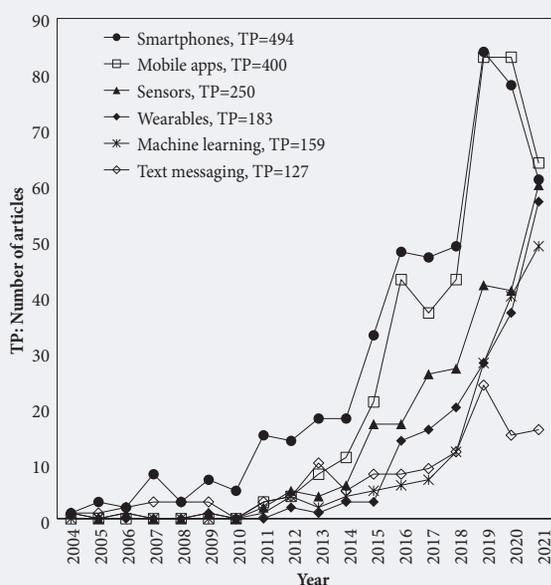
advances include the integration of smart devices, artificial intelligence, and digital interfaces powered by mobile applications to facilitate diabetes care. Some studies validated the effectiveness of a telemedicine strategy integrated with a mobile application and web portal to monitor a basal-bolus insulin therapy in diabetic patients (Franc et al., 2020; Hernandez-Ordóñez et al., 2020).

The research topic of “sensors” involves the use of sensor technology to detect and measure changes in the environment in response to physical or chemical stimuli such as temperature, pressure, light, proximity, sound, motion, etc. In healthcare, sensors are useful for monitoring vital signs, tracking physical activity and medication adherence, detecting irregular behaviors, etc. The number of articles associated with this topic is 250. Recent advances emphasize the integration of multiple sensors to obtain parameters in a noninvasive manner, providing timely warning on adverse conditions and promoting actions to improve diabetes control and treatment. Sawaryn et al. (2021) presented the advantages of sensors to identify movements and postures, useful for estimating energy expenditure and ensuring correct hormone administration in a Bi-Hormonal Artificial Pancreas system. Baig et al. (2021) validated the effectiveness of using sensors in a wearable body vest, Internet of Things (IoT) monitoring, and artificial intelligence algorithms to detect prediabetes and type 2 diabetes.

The research topic of “wearables” refers to a technology device that is placed on the body in the form of an accessory or clothing to perform a specific function. Typically, wearables incorporate sensors and wireless communication to share information, useful for health monitoring and fitness tracking. There are 183 articles on this topic. Recent advances in wearables have emphasized their accessory form and mechanisms to measure glucose using non-invasive resources such as sweat, tears, and urine. Advances are also being made to deliver medication and indicate risk conditions for developing diabetic complications. Smart devices such as socks, clothing, diapers, mouthguards, and contact lenses are underlined. There are proposals to use a smart sock with infrared thermography to control the temperature of different regions of the foot to prevent diabetes-related problems such as ulceration and infection (Torreblanca-González et al., 2021; Beach et al., 2021). Arakawa et al. (2020) validated a wearable mouthguard biosensor to obtain glucose concentrations in human saliva that correlate with blood sugar levels, enabling noninvasive glucose monitoring for diabetic patients.

The research topic of “machine learning” covers computer algorithms that are trained to recognize and analyze patterns in large data sets for learning and decision-making activities to improve the performance of a task. Machine learning algorithms can be useful for analyzing data to determine diagnoses and health conditions, to develop personalized treatment plans, to predict patient outcomes and to provide tailored recommendations. The total number of articles on this topic is 159. There has been remarkable progress in machine learning algorithms to predict possible diabetes health conditions, using data from videos and images in addition to text. Besides, the incorporation of machine learning into digital platforms and smart devices is also highlighted. Nasser et al. (2021) verified the accuracy of a cloud-based deep learning algorithm combined with the Internet of Things (IoT) technologies for diabetes monitoring, providing patients with a prediction of future glucose levels. Stolfi and Castiglione (2021) confirmed the effectiveness of

Figure 3. The main research topics and their development trends in the technologies category



Source: authors.

an emulator based on complex simulations using machine learning methods that incorporate metabolic, nutritional, and lifestyle data to predict the development of type 2 diabetes, enabling its application on mobile devices to perform self-management activities. Islam et al. (2021) proposed a machine-learning algorithm to detect noninvasive glucose levels based on videos of an individual's fingertip via smartphone cameras, which are processed into a photoplethysmography (PPG) signal.

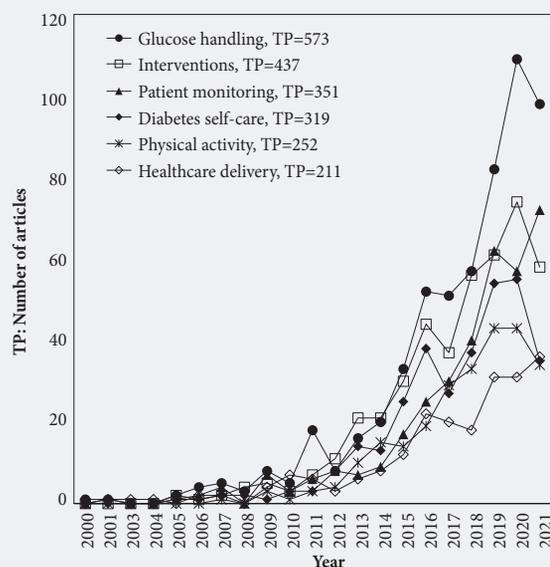
Finally, the research topic of “text messaging” describes the exchange of text messages through cellular or digital networks, using mobile devices or computers. The number of articles linked to this topic is 127. Automatic generation of personalized messages reminds patients of timely glucose control, encourages physical activity (Aguilera et al., 2020; Kundury et al., 2020).

Category 3. Applications

This category includes topics where mHealth has been applied to provide solutions to various diabetes issues. Through the continuous advances in this technology, novel and innovative applications in diabetes care are likely to emerge that will change the way this disease is controlled and managed. **Table A4** shows the research topics in this category according to their rank. As mentioned before, the number of articles that each supporting word appears in either article titles, author keywords, and keywords plus were summed to determine the corresponding rank.

Glucose handling, interventions, patient monitoring, diabetes self-care, physical activity, and healthcare delivery are the top six research topics. Figure 4 presents a graph with the number of articles containing in their title, author keywords and keyword plus, the supporting words corresponding to each of the top six topics, distributed by year of publication. This graph allows the identification of the focus in the applications category and its evolutionary trends.

Figure 4. The main research topics and their development trends in the applications category



Source: authors.

The research topic “glucose handling” considers the context of the glucose control process, involving glucose detection, regular blood glucose testing, maintenance of blood sugar close to healthy levels, etc. The number of articles associated with this topic is 573. Recent advances in this field are considering non-invasive alternatives to measure glucose levels, such as sweat and tears. Vaquer et al. (2021) demonstrated the efficacy of a mobile colorimetric wearable biosensor for detecting glucose concentration in sweat, comprising filter paper, a sweat volume sensor, and a color chart for signal normalization. This can be used with a smartphone camera to read the signal. Wang et al. (2018) developed a multilayer modified test paper to detect glucose concentration supported by a smartphone as a reading signal. This provides non-invasive detection of glucose levels based on tear samples. Pustozarov et al. (2020) developed a model to predict postprandial glucose patterns using a decision tree gradient boosting algorithm, based on information from a mobile app where individuals registered their food habits and context.

The research topic of “interventions” includes the context of actions undertaken to prevent, treat and improve diabetes outcomes. Patients are encouraged to learn about their glucose instability and a lifestyle that produces favorable conditions to improve their health, such as exercise, stress reduction, and healthy diet. There are 437 articles associated with this theme. Notable developments in using mobile technologies such as smartphones, apps, IoT, and smart wearables have been made to conduct intervention activities. Kato et al. (2020) revealed the effectiveness of an Internet of Things (IoT)-based lifestyle intervention, including remote health guidance and wearable devices to improve diabetes control.

The research topic of “patient monitoring” considers the context of processes that enable continuous monitoring of a patient's health. It includes remote monitoring of health behaviors, alerts in case of health changes that may have a negative impact, and continuous measurement of vital pa-

rameters such as temperature, blood pressure, pulse, blood oxygen saturation, etc. The number of articles related to this topic is 351. Progress has been made around the architecture to connect multiple technologies such as the Internet of Things (IoT), smartphones, and smart wearables for monitoring diabetic patients. Rghioui et al. (2020) effectively developed a smart architecture based on machine learning algorithms to connect smart devices and sensors for patient monitoring.

The research topic of “diabetes self-care” refers to the set of activities and habits that diabetic patients have to do on their own to achieve better control of their disease and prevent complications. Patient education is necessary to facilitate knowledge and collaborative participation with health professionals to develop self-management skills such as self-monitoring of glucose, consumption of healthy diets, regular exercise, adequate intake of medications, constant control of feet and eyes to avoid complications, etc. There are 319 articles on this topic. Significant progress in this field comes from digital platforms such as mobile apps and their integration with wearable devices. Luo and White-Means (2021) confirmed the feasibility of using mobile apps as a low-cost resource for conducting diabetes self-management activities in underserved diabetic patients with limited access to primary care providers.

The research topic of “physical activity” includes the context of the body movements that involve energy expenditure, such as exercise, walking, aerobic and fitness activities, etc. The total number of articles on this topic is 252. Advances in wearables with innovative designs and mobile apps to track physical activity have been identified. Li et al. (2021b) validated the efficiency of exercising supported by a chest band wearable and mobile application compared with traditional exercise. Ehrlich et al. (2021) confirmed the effectiveness of a wrist wearable to track physical activity in women with gestational diabetes. Martinato et al. (2021) demonstrated the accuracy of a smartwatch to monitor physical activity in aged adults.

Finally, the research topic of “healthcare delivery” examines the context of the provision of medical care to patients through interactions with healthcare professionals, such as consultations, medical services, recommendations, examinations, diagnoses, treatments, procedures, etc. The overall number of articles in this theme is 211. There have been advances in communication challenges and remote alternatives for clinical consultation and care delivery using digital technologies. Shaw et al. (2020) identified effective communication strategies to improve the quality of interactions through video consultations.

Conclusion

Mobile health is in a phase of rapid development. There is a dynamic flow of emerging opportunities to improve prevention and timely interventions to improve health. This is especially evident in diabetic diseases and related complications. Research in this area is particularly relevant given the projections of increasing diabetes dynamics that predict a 25% increase in the number of patients every next 10-15 years (IDE, 2021). Smart applications based on AI and virtual reality are expected to create advanced solutions that provide a new quality of life, reduce risks and enhance physiological well-being.

The word distribution analysis allowed the identification of research topics on Diabetes mHealth for understanding their progress, which is useful for the decision-making process regarding Research, Development (R&D), and Innovation. A total of 141 research topics were identified, and grouped into six categories: Health problems, technologies, applications, global perspectives, population groups, and healthcare professionals. An overview of the top three categories with more research topics was developed. Diabetes mHealth represents an innovative alternative to improve the control of this disease by using mobile technology to improve blood glucose levels. The main specific health problems addressed by mHealth were type 2 diabetes mellitus, gestational diabetes mellitus, cardiovascular disease, type 1 diabetes mellitus, and chronic diseases, as well as related complications such as diabetic retinopathy and diabetic foot, and obesity as a risk factor. Machine learning algorithms, mobile applications, and smart devices are making remarkable advances in diabetes detection, control, and management, enabling care anytime, anywhere.

The main technologies employed in Diabetes mHealth research were smartphone, also known as mobile phone, followed by mobile applications, which are software developed for mobile devices, commonly known as mobile apps, mobile applications, app, and apps. Then comes sensors, which are mainly used in wearables and IoT to detect physical impulses and convert them into electrical and digital signals for further analysis. Next are wearables that are useful for health monitoring and physical activity tracking. Then is text messaging, which is useful for establishing communication between healthcare professionals and between healthcare professionals and patients. Finally, machine learning, which helps identify patterns and make predictions based on large amounts of information. Internet of Things (IoT) is evolving in Diabetes mHealth research, which integrates wireless devices and wearables to create systems that facilitate healthcare delivery and monitoring. These technologies promote the empowerment of patients to participate in self-management and educational activities necessary to control their health conditions and make more effective joint decisions with their physicians. The main applications of diabetes mHealth comprises activities such as glucose handling, interventions, patient monitoring, diabetes self-care, physical activity, and healthcare delivery.

Medical practices supported by mobile technologies present several challenges. Remote connections miss the opportunity of practicing detailed physical exams, reduce interaction with nonverbal signs that are important for effective communication, in addition bias regarding the context of patients living conditions that influence their health may be present. Moreover, since patients have different levels of access to technology and education this can result in poor individual health engagement. However, mHealth advances intend to enhance health care professional services and arrive to the highest number of people; it provides solutions for distance locations where the number of healthcare professionals is reduced. The uniqueness of mHealth lies in the opportunity of linking patients to health services in a more extensive way. Public health management strategies aligned with digital health efforts can reduce health disparities improving health care access for vulnerable populations. In addition, public health will be influenced by AI and IoT on how to cope with large volumes of information regarding

the social complexity of this illness, providing more efficient solutions to determine regions of high prevalence, demographic groups, access to health services, even factors that may be triggering diabetes complications. The final aim is to allocate resources more efficiently, anticipate health issues, enhance education programs to prevent and improve control of the disease, promoting equitable access to health.

Considering the current knowledge of research topics in Diabetes mHealth, future studies should identify technological advances in patents, policies, regulations, and ethical issues related to the field. The research topics identified in this study provide insights for researchers, decision makers, and policy makers to prioritize their R&D efforts, effectively

consolidate their areas of interest and explore new topics with innovative and practical solutions. This supports the growth of the field by providing a panorama for future research directions to address the challenges of diabetes and its impact on society through mobile technology and digital developments.

We acknowledge the institutional funding received from Tecnológico de Monterrey, and the National Council of Humanities, Science and Technology of Mexico (CONAHCYT) through Graduate Studies Scholarships and Academic Scholarships provided by CONAHCYT as members of the National System of Researchers (Sistema Nacional de Investigadores). The authors declare that they do not have any conflicts of interest.

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APPENDICES

Table A1. Top 50 most frequent terms in title, author keywords and keywords plus

Words in title	TP	R (%)	Author keywords	TP	R (%)	Keywords Plus	TP	R (%)
diabetes	725	1 (46)	diabetes	238	1 (19)	care	205	1 (15)
mobile	347	2 (22)	mHealth	193	2 (15)	management	194	2 (14)
type	336	3 (21)	diabetes mellitus	132	3 (10)	glycemic control	171	3 (12)
patients	256	4 (16)	mobile health	127	4 (10)	adults	134	4 (10)
trial	244	5 (16)	telemedicine	122	5 (10)	health	124	5 (8.8)
health	237	6 (15)	self-management	98	6 (7.7)	risk	122	6 (8.7)
controlled	191	7 (12)	type 2 diabetes	91	7 (7.1)	intervention	120	7 (8.5)
glucose	173	8 (11)	smartphone	85	8 (6.7)	system	112	8 (7.9)
randomized	171	9 (11)	mobile phone	66	9 (5.2)	self-management	107	9 (7.6)
system	170	10 (11)	type 1 diabetes	61	10 (4.8)	physical-activity	93	10 (6.6)
intervention	142	11 (9)	ehealth	58	11 (4.5)	mellitus	92	11 (6.5)
care	137	12 (8.7)	physical activity	52	12 (4.1)	prevalence	90	12 (6.4)
monitoring	137	12 (8.7)	mobile applications	41	13 (3.2)	interventions	82	13 (5.8)
diabetic	129	14 (8.2)	machine learning	37	14 (2.9)	technology	82	13 (5.8)
management	128	15 (8.1)	type 2 diabetes mellitus	36	15 (2.8)	outcomes	78	15 (5.5)
app	117	16 (7.4)	digital health	35	16 (2.7)	metaanalysis	73	16 (5.2)
self-management	114	17 (7.2)	hypertension	33	17 (2.6)	support	72	17 (5.1)
mellitus	104	18 (6.6)	self-care	33	17 (2.6)	adherence	66	18 (4.7)
smartphone	104	18 (6.6)	telehealth	33	17 (2.6)	disease	66	18 (4.7)
support	100	20 (6.4)	obesity	32	20 (2.5)	impact	65	20 (4.6)
wearable	98	21 (6.2)	mobile apps	31	21 (2.4)	prevention	65	20 (4.6)
control	95	22 (6)	technology	31	21 (2.4)	people	64	22 (4.5)
adults	89	23 (5.7)	chronic disease	29	23 (2.3)	association	56	23 (4)
activity	78	24 (5)	e-health	27	24 (2.1)	validation	54	24 (3.8)
analysis	78	24 (5)	continuous glucose monitoring	26	25 (2)	children	53	25 (3.8)
phone	76	26 (4.8)	exercise	25	26 (2)	blood-glucose	51	26 (3.6)
protocol	76	26 (4.8)	glucose	25	26 (2)	glucose	51	26 (3.6)
technology	74	28 (4.7)	text messaging	25	26 (2)	adolescents	50	28 (3.5)
risk	72	29 (4.6)	artificial intelligence	24	29 (1.9)	education	48	29 (3.4)
mHealth	70	30 (4.4)	diabetic retinopathy	23	30 (1.8)	exercise	48	29 (3.4)
blood	68	31 (4.3)	internet	23	30 (1.8)	obesity	48	29 (3.4)
evaluation	67	32 (4.3)	primary care	23	30 (1.8)	internet	45	32 (3.2)
physical	63	33 (4)	gestational diabetes	22	33 (1.7)	program	43	33 (3)
development	62	34 (3.9)	internet of things	22	33 (1.7)	health-care	42	34 (3)
clinical	61	35 (3.9)	m-health	22	33 (1.7)	design	41	35 (2.9)
feasibility	58	36 (3.7)	randomized controlled trial	22	33 (1.7)	randomized controlled-trial	40	36 (2.8)
insulin	58	36 (3.7)	blood glucose	21	37 (1.6)	telemedicine	40	36 (2.8)
digital	57	38 (3.6)	qualitative research	21	37 (1.6)	efficacy	38	38 (2.7)
patient	57	38 (3.6)	gestational diabetes mellitus	20	39 (1.6)	hypoglycemia	37	39 (2.6)
people	57	38 (3.6)	mobile application	20	39 (1.6)	model	37	39 (2.6)
disease	55	41 (3.5)	sensors	20	39 (1.6)	mortality	37	39 (2.6)
randomised	55	41 (3.5)	type 2	20	39 (1.6)	therapy	37	39 (2.6)
apps	54	43 (3.4)	prevention	19	43 (1.5)	complications	35	43 (2.5)
improve	54	43 (3.4)	app	18	44 (1.4)	life-style intervention	35	43 (2.5)
assessment	53	45 (3.4)	hba1c	18	44 (1.4)	behavior	32	45 (2.3)
gestational	53	45 (3.4)	prediabetes	18	44 (1.4)	cardiovascular-disease	32	45 (2.3)
pilot	53	45 (3.4)	wearable sensors	18	44 (1.4)	quality-of-life	32	45 (2.3)
program	51	48 (3.2)	adherence	17	48 (1.3)	trial	32	45 (2.3)
detection	50	49 (3.2)	cellular phone	17	48 (1.3)	weight-loss	32	45 (2.3)
design	49	50 (3.1)	diabetes management	17	48 (1.3)	quality	31	50 (2.2)

Note: TP: Number of articles; R (%): Ranking and percentage of the number of articles compared to the total number of articles.

Source: authors.

Table A2. Research topics of health problems with their supporting words

Rank	Research topic	Supporting words from title, author keywords, and keywords plus	TS
<i>Sub-category "Diseases"</i>			
1	Type 2 Diabetes mellitus	diabetes mellitus type 2, "diabetes mellitus, type 2", diabetes type 2, t2dm, type 2, type 2 diabetes, type 2 diabetes mellitus, type-2, type-2 diabetes mellitus, type-2 diabetes-mellitus	212
2	Gestational diabetes mellitus	gestational, gestational diabetes, gestational diabetes mellitus, gestational diabetes-mellitus, gdm, antenatal care, neonatal, maternal, maternal health, pregnancy, pregnant, pregnant-women, postpartum, gestational weight-gain, maternal obesity	196
3	Cardiovascular diseases	cardiovascular, cardiovascular disease, cardiovascular diseases, cardiovascular outcomes, cardiovascular risk factors, cardiovascular risk-factors, cardiovascular-disease, vasculature, heart-disease, heart-failure, heart-rate, heart-rate-variability, cardiac, cardiac rehabilitation, cardiometabolic	142
4	Type 1 diabetes mellitus	diabetes mellitus type 1, "diabetes mellitus, type 1", iddm, type 1, type 1 diabetes, type 1 diabetes mellitus, type-1	120
5	Chronic diseases	chronic, chronic conditions, long-term, chronic disease, chronic diseases, chronic disease management, chronic illness	120
6	Coronary-heart-disease	coronary, coronary-heart-disease, artery	20
7	Cancer	cancer	18
8	Non-communicable diseases	non-communicable, non-communicable disease, non-communicable diseases, noncommunicable diseases	18
9	Comorbid	comorbid, comorbid depression, comorbidity	13
10	Covid-19	covid-19, pandemic	13
11	Asthma	asthma	5
12	Chronic obstructive pulmonary disease	copd	4
13	Multiple sclerosis	multiple sclerosis	3
<i>Sub-category "Diabetic complications"</i>			
1	Diabetic retinopathy	diabetic retinopathy, diabetic-retinopathy, retinal, retina, retinal images, retinal imaging, retinopathy, microvascular complications, ophthalmology, ophthalmoscopy, eye diseases, macular, macular edema, ocular, optical, optical coherence tomography, slit-lamp biomicroscopy, tele-ophthalmology, tele-ophthalmology, visual acuity, acuity, blindness, hyperacuity, edema	180
2	Diabetic foot	Diabetic foot, diabetic foot ulcer, diabetic foot ulcers, amputations, gait, foot, foot ulcers, ulcer, ulceration, ulcers, plantar, plantar pressures, thermal, thermography	134
3	Wound healing	wound, wound healing, healing, wounds, infection, epidermal, skin, transdermal, chronic wounds, impairment, dressing	66
4	Hypoglycemia	hypoglycemia, hypoglycaemia, severe hypoglycemia	65
5	Diabetic peripheral neuropathy	diabetic peripheral neuropathy, neuropathy, nerve, joint, peripheral, pain	34
6	Diabetic nephropathy	diabetic nephropathy, kidney, chronic kidney-disease	13
7	Ketoacidosis	ketoacidosis, acid	12
<i>Sub-category "Risk factors"</i>			
1	Obesity	obese, obese adults, obesity, overweight	144
2	Hypertension	hypertension, hypertensive	95
3	Metabolic syndrome	metabolic, metabolic health, metabolic syndrome, syndrome, metabolic-control, metabolism, metabolite	60
4	Insulin resistance	insulin resistance, resistance, insulin sensitivity, insulin-resistance, cells, dna, beta-cell function	41
5	Prediabetes	pre-diabetes, prediabetes	40
6	Hyperglycemia	hyperglycemia	30
7	Sedentary behavior	sedentary, sedentary behavior, sitting	18
8	Smoking	smoking, smoking-cessation	9
<i>Sub-category "Complications"</i>			
1	Atrial fibrillation	atrial, atrial fibrillation, atrial-fibrillation, fibrillation	26
2	Myocardial-infarction	acute, acute myocardial-infarction, myocardial-infarction, infarction, ischemia	17
3	Stroke	stroke	16

Note: TS: The total sum is the addition of the number of articles that each supporting word appears in either article titles, author keywords, and keywords plus.
Source: authors.

Table A3. Research topics of Diabetes mHealth technologies with their supporting words

Rank	Research topic	Supporting words from title, author keywords, and keywords plus	TS
1	Smartphones	cell, cell phone, cell phones, cell-phone, cellphone, cellular, cellular phone, cellular phone, smartphone, smartphone-based, smartphone-powered, smartphone-enabled, smartphones, phone, phone-based, phones, telephone, mobile phone, mobile phone technology, mobile phones, radiation, photography	594
2	Mobile Apps	app, app-based, apps, health apps, mobile app, mobile application, mobile applications, mobile apps, mobile health applications, mobile phone applications, phone applications, smartphone app, smartphone application, smartphone application (app), smartphone applications, smartphone apps, application, applications, apple, android, diabetes apps	440
3	Sensors	sensing, sensing technology, sensitive, sensitivity, sensor, sensor-based, sensors, wearable sensor, wearable sensors, electrochemical, electromagnetic, energy harvesting, magnetic, calibration, self-powered, remote sensing technology, glucose sensor, optical sensors, wireless sensor networks, temperature sensors, accelerometer, accelerometers, accelerometry	269
4	Wearables	wearable, wearable computing, wearable device, wearable devices, wearable electronic devices, wearable electronics, wearable system, wearable technology, wearables, portable, wristband	188
5	Text messaging	message, message-based, messages, messaging, messaging system, short message service, short-message service, sms, text message, text messages, text messaging, text-med, text-messaging, chat	171
6	Machine learning	machine learning, deep learning, pattern recognition, patterns, algorithm, algorithms, mpc, artificial neural networks, neural networks, convolutional, convolutional neural network, classification, classifier	165
7	Internet	internet, internet use, internet-based, net, network, networks, wireless, wireless communication, architecture	162
8	Artificial intelligence	artificial intelligence, ai, reinforcement learning, offline, ontology, taxonomy, online, computer vision, computational modeling, computer, computer-based, computerized, simulation, image processing, image-based, images, imaging	153
9	Artificial pancreas	artificial pancreas, bionic pancreas, artificial, pancreas, implantable	103
10	Medical devices	device, devices, medical devices	101
11	Big data	big data, big, data mining, data models, data-driven, information, information-seeking, search	91
12	Internet of things (IoT)	internet of things, internet of things (iot), iot, iot-based, things	75
13	Biosensor	biosensing, biosensor, biosensors, mouthguard biosensor, optical biosensor	65
14	Smart contact lens	lens, lenses, contact, smart, tear glucose	65
15	Web-based	web, web-based, patient portal, portal, content	57
16	Video games	video games, video, videos, game, games	27
17	Cloud computing	cloud, cloud computing, cloud-based	24
18	Fundus camera	fundus, fundus photography, retinal camera	20
19	Virtual reality	virtual, augmented	16
20	Calls	call, calls, automated calls	13
21	Tablet	tablet, tablet-based, screen	11
22	Voice assistant	voice, assistant, assisted	11
23	Blockchain	Blockchain	10
24	Electrocardiogram	electrocardiogram, ecg	10
25	Photoplethysmography	Photoplethysmography	9
26	Glucometer	Glucometer	7
27	Infrared thermography	infrared thermography	6
28	Spectroscopy	spectroscopy, near-infrared	6
29	3D-Printing	3d-printed	4

Note: TS: The total sum is the addition of the number of articles that each supporting word appears in either article titles, author keywords, and keywords plus.

Source: authors.

Table A4. Research topics of Diabetes mHealth applications with their supporting words

Research topic	Research topics of Diabetes mHealth applications with their supporting words	TS
Glucose handling	glucose, glucose control, glucose detection, glucose oxidase, glucose-tolerance, impaired glucose-tolerance, loop glucose control, overnight glucose control, sugar, glycaemia, glycaemic, glycaemic control, glycemic, glycemic control, glycemic index, blood glucose, ambulatory glucose profile, blood glucose monitoring, blood glucose self-monitoring, blood-glucose, blood-glucose control, self-monitoring of blood glucose, plasma-glucose, hba, hba(1c), hba1c, 1c, a1c, fasting, hemoglobin, glycosylated haemoglobin, glycated hemoglobin a1c, biomarker, biomarkers, strip, basal, postprandial, ppg	755
Interventions	intervention, interventions, complex intervention, complex interventions, life-style intervention, life-style interventions, lifestyle intervention, multifactorial intervention, motivational interviewing, emid	443
Patient monitoring	health monitoring, monitor, monitored, monitoring, monitoring-system, monitors, follow-up, patient monitoring, remote monitoring, home health monitoring, home-based, home-use, telemonitoring, tracker, trackers, tracking, biomedical monitoring, self-monitoring, self-tracking, continuous glucose monitoring, continuous glucose monitoring (cgm), cgm, glucose monitoring, glucose monitoring-system, patch, non-invasive, noninvasive, invasive	434
Diabetes self-care	diabetes self-management, self-management, self-management support, self care, self-care	401
Physical activity	exercise, aerobic exercise, activation, activity recognition, activity tracker, fitness, motor activity, physical, physical activity, physical-activity, cardiorespiratory fitness, free-living, free-living conditions, walking, energy expenditure, energy-expenditure	388
Healthcare delivery	telemedical, telemedicine, telemedicine system, remote consultation, medical services, interactions, interactive, interactive diary, providers, delivery of health care	252
Medication adherence	adherence, improve adherence, medication adherence, medication, patient compliance, compliance, nonadherence, reminder, reminder system, reminders, medicine	251
Diabetes education	diabetes education, education, educational, health education, health literacy, literacy, management education, patient education, self-management education, training, coaching, retention, awareness, health coaching, learned, lessons	246
Usability evaluation	usability, usability evaluation, usage, usefulness, utility, utilization, utilizing, efficient, user, users, user acceptance, user centered design, user-centered, user-centered design, profile, profiles, performance, heuristic, heuristic evaluation, evaluation studies, experience, experienced, experiences	245
Behavior change	behavior, behavior change, behavior modification, behavior-change, behavior-change techniques, behavioral, behavioral medicine, behaviors, behaviour, behaviour change, behavioural, health behavior, intention, self-efficacy, change, changes, readiness	245
Treatment	therapy, therapeutic, counseling, counselling, acceptability, acceptance, acceptance and commitment therapy, intensive, treat, treated, treatment, guidance, guidelines, recommendation, recommendations, recommender system, position statement, adoption, rehabilitation, clinical-practice guidelines	242
Patient examination	diagnosed, diagnosis, diagnostic, diagnostics, disease diagnosis, detect, detection, simultaneous, examining, newly, exploratory, exploring, screening, recognition, determinants, determination, determine, evaluate, evaluating, indicators	234
Healthy lifestyle	life, life-style, lifestyle, lifestyle modification, lifestyles, health-related quality of life, healthy, healthy lifestyle, quality, quality of life, quality-of-life	225
Decision-support-systems	decision, decision support, decision-support, decision support systems, decision-support-systems, decision-making, support, supporting, clinical decision support, clinical decision support system	222
Food-intake	diet, diet monitoring, dietary, bolus, bolus calculator, calculation, calculator, counting, carbohydrate, carbohydrate counting, disorder, disorders, eating, energy-efficient, energy-intake, food, food-intake, food recognition, intake, meal, meal-time, erionalized, nutrition, nutrition assessment, nutritional, protein	219
Diabetes prevention	diabetes prevention, prevent, prevention, prevention program, preventive, preventive medicine, primary prevention, perceived, perception, perceptions, secondary, secondary prevention	213
Personalized medicine	personal, personalized, personalization, personalized, personalized medicine, tailored, precision, precision medicine, predict, predicting, prediction, predictive, predictive models, predictive-validity, predictors, model-predictive control, prognosis, prospective	168
Insulin delivery-system	insulin delivery, insulin delivery-system, automated insulin delivery, insulin injections, multiple daily injections, insulin pump, insulin pump therapy, loop insulin delivery, insulin-treated, intensive insulin therapy, insulin therapy, insulin, titration, pump, pump therapy	166
Mental health	distress, anxiety, psychological, psychological distress, psychosocial, depression, depressive, phq-9, mindfulness, rationale, balance, mental, mental health, mental-health, cognitive, cognitive-behavior therapy, stress, sleep, night, nocturnal	159
Weight control	weight, weight loss, weight management, weight-gain, weight-loss, weight-loss interventions, body, body composition, body weight, body-mass index, waist circumference, gain	146
Patient empowerment	patient engagement, patient empowerment, patient participation, patient satisfaction, patient-centered, patient-centered care, satisfaction, self-efficacy, treatment satisfaction, motivation, encourage, nudge, empowerment, empowerment scale, do-it-yourself, self-reported, engage, engagement	132
Electronic health record	electronic health record, electronic health records, electronic medical record, health records, health information, record, records, patient-generated, patient-generated data, patient-generated health data, sharing, documentation, personal health record, personal health records, phr, history, interoperability, electronic	115
Social support	social support, social, social media, media, culturally, context, focus, focus groups, family, group, groups, help, peer, peer support, peer support	110
Health promotion	health communication, health promotion, promote, promoting, promotion, communication, dissemination	78
Blood-pressure control	blood pressure, blood-pressure, blood-pressure control, pressure	64
Diabetes management	diabetes management, care management, disease management, health management, management-system, managing, control 1 st	61
Health policy	health policy, standard, financial incentives, incentives, privacy, willingness, willingness-to-pay	29

Note: The total sum is the addition of the number of articles that each supporting word appears in either article titles, author keywords, and keywords plus. *Source:* authors.