# 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

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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 putting in great effort 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 empowers 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 furthermore has a significant impact on chronic disease management. For example, thanks to the 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 trillion (IDF, 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 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 and Development (R&D) and Innovation. The aim of our study is to fill this 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

Word distribution analysis involves a set of scientific literature documents and a word partition of their article titles, author keywords, and keywords plus[1] to reveal the main research topics (Wang, Ho, 2016). Identifying research topics within this field can help researchers, academics, industry, decision-makers, and policymakers to prioritize their R&D efforts, and provide 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 Analytics.[2] 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 1,848 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 1,668 articles that represented 90% of the original 1,848 articles. Further manual analysis was conducted obtaining 1,574 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 focus (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 1,574 retrieved documents. Stop words such as prepositions, conjunctions, pronouns, articles, and so on were removed as they were irrelevant to the analysis.

In the case of the title, the phrases were divided into single words to perform statistical analysis. The title contains significant information with details that an author uses to denote the relevance of the topic discussed, becoming the first view for the reader. This information contributes to identifying the focus and emphasis of studies. A total of 3,467 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 ranking according to the number of articles containing the word in the 1,574 retrieved documents.

[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.

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 3,274 author keywords were identified. However, only 419 of them appeared in three or more articles. This means that 2,523 keywords appeared in only one article and 332 keywords appeared in two articles, probably indicating different research foci and a discontinuity in topics. Table A1 shows the top 50 most frequently used 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 2,287 Keywords Plus were identified. Table A1 shows the top 50 most frequently used Keywords 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 of 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 integrated terms. The word distribution analysis provides relevant clues, subjective focus, and the 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 weaknesses exhibited by a 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 1,876 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 for determining 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 the most 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*

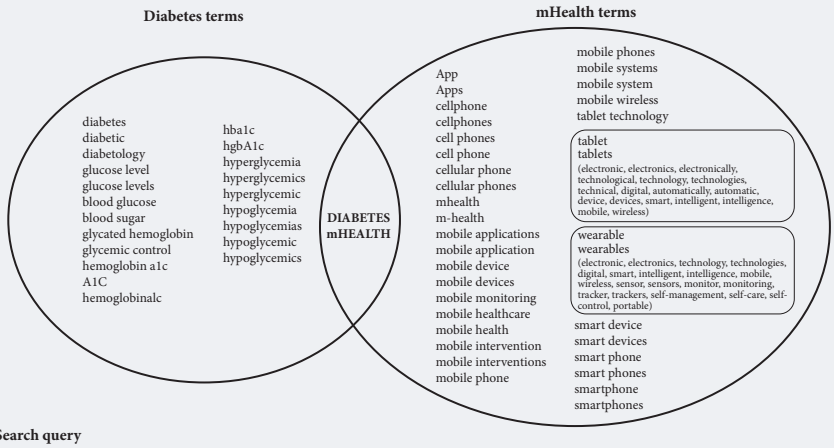
This category contains research topics where mHealth has been contributing to solving diabetes health problems, including by identifying diseases, complications, risk factors, and medical conditions, which can be considered sub-categories of "health problems". **Table A2** lists the research topics identified in this category by rank and subcategory.

These sub-categories diseases, diabetic complications, risk factors, and complications, consider 13, seven, eight, and three 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 Keywords 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 body, especially in the eyes, heart, feet, nerves, and kidneys. To cope with it, it is important to make lifestyle changes such as improving diet and exercise habits, taking medications properly, and undergoing 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. An instant messaging social networking app can be beneficial to increasing the knowledge on self-care activities and improving 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, carbohydrate intake control, and exercise are required to reduce the risk of developing other complications. A total of 185 articles are on this topic.

## Figure 1. **Venn Diagram of Diabetes mHealth Terms and the Resulting Query**




**Search query**

((TS=((«diabetes» or «diabetic» or «diabetology» or «glucose level» or «glucose levels» or «blood glucose» or «blood sugar» or «glycated hemoglobin» or «glycemic control» or «hemoglobin a1c» or «A1C» or «hemoglobinalc» or «hba1c» or «HgbA1c» or «hyperglycemia» or «hyperglycemics» or «hyperglycemic» or «hypoglycemia» or «hypoglycemias» or «hypoglycemic» or «hypogtycemlcs» and («app» or «apps» or «cellphone» or «cell phones» or «cell phone» or «cellular phone» or «cellular phones» or «cellphones» or «mhealth» or «m-health» or «mobile applications» or «mobile application» or «mobile device» or «mobile devices» or «mobile monitoring» or «mobile health» or «mobile healthcare» or «mobile intervention» or «mobile interventions» or «mobile phone» or «mobile phones» or «mobile systems» or «mobile system» or «mobile wireless» or «smart device» or «smart devices» or «smart phone» or «smart phones» or «smartphone» or «smartphones» or («wearable» or «wearables») and («electronic» or «electronics» or «technology» or «technologies» or «digital» or «smart» or «intelligent» or «intelligence» or «mobile» or «Wireless» or «sensor» or «sensors» or «monitor» or «monitoring» or «tracker» or «trackers» or «self-management» or «self-care» or «self-control» or «portable»)) or «tablet technology» or ((«tablet» or «tablets; and («electronic» or «electronics» or «electronically» or «technological» or «technology» or «technologies» or «technical» or «digital» or «automatically» or «automatic» or «device» or «devices» or «smart» or «intelligent» or «intelligence» or «mobile» or «wireless»)))))
NOT (TS=(«acute-phase» or «amyloid» or «adzuki» or «glycosidase» or «pollock» or «polyphenol» or «precursor» or «secretase» or «antiplasmin» or «mu(app)» or «peak pressure» or «polyphosphate» or «pK(a,app)» or «phosphatase» or «actinobacillus» or «APP/AuNPs» or «P-app» or «k(2,app)» or «k(app)» or «propranolol» or «APP-10» or «pyelonephritis» or «polysaccharide» or «K-m(app)» or «apolipoprotein» or «K(m)» or «polysaccharide» or «polypeptide» or «artemisia» or «agouti» or «K-I app» or «Delta g» or «mutations» or «zucker» or «APP/PS1 « or «serum selenium» or «pulse pressure (APP)» or «patency» or «zygomycosis» or «BACE1» or «S-nitrosylation» or «phosphorylation» or «advanced practice providers» or «Ag/AgCl» or «Pi3K» or «DEGs» or «vanadium» or «pyrrole» or «oxidant» or «inhibitor» or «DPP4is» or «matrix tablet» or «tablet-dispensing» or «disintegrating tablet» or «capsule» or «ginkgo» or «alogliptin» or «benzoate» or «repaglinide» or «dissolution» or «pump tablet» or «pump tablets» or «tablet dosage» or «placebo» or «poly-DL-lactic» or «acetylation» or «acetyl» or «radical» or «hydrochloride» or «uniformity of tablets» or «paliperidone» or «monolayer» or «mitochondrial» or «number of tablets» or «single-tablet» or «orodispersible tablets» or «release tablet» or «formulation» or «oral medicines» or «metanol» or «sitagliptin» or «chlorine» or «ethambutol» or «denervation» or «vaspin» or «SYKFT» or «mimetic» or «dissolvable» or «HPLC» or «JQJTT» or «implantable devices» or «nanostructure» or «raman spectroscopy» or «TEOS» or «ACF» or «MoS2» or «Zn+2' or «OCMC» or «SPEs» or «CVD-grown» or «Dirac» or «UHPLC» or «polyimide» or «TENGs» or «PEDOT» or «WSNF» or «SCE» or «EBFCs» or «FPCB» or «NSCLC» or «HED» or «hydroxychloroquine» or «subfertile» or «tuber» or «cleansing» or «meses» or «PCOS» or «PICC» or «OKO» or «1AF» or «CIPN» or «POAP» or «hs-CRP» or «nCoV-19» or «CPB» or «MCCOD» or «PSG» or «L-Asp» or «MeSHDD» or « JoVE» or «D-3» or «TRAP» or «RASGD» or «mobile clinics» or «mobile clinic» or «JIF» or «mobile health promotion» or «mobile health unit» or «mobile healthcare service» or «mobile health service» or «health data linkage unit» or «mobile health camp» or «mobile health van»))) and PY=1998-2021 and DT=article

*Source:* authors.

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 Type 1 diabetes mellitus. 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 Type 1 diabetes mellitus, 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 being 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, behavioral changes, and the control of cardiovascular disease. Ernsting et al. (2019) identified the need for digital literacy and behavioral 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, and behavioral limitations. 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 toward 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 deteriorations in one's 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. Jebaseeli et al. (2020) proposed an Internet of Things (IoT) framework for diabetic retinopathy diagnosis based on sensors, information sharing, and mobile applications that has reached 99.58% accuracy.

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

Table 1. **The General Description of the 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 |

*Source*: authors.

oping various health problems such as Type 2 diabetes, heart disease, high blood pressure, high 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 mobile lifestyle interventions to reduce body weight, glucose levels, and lipid metabolism in overweight or obese 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)

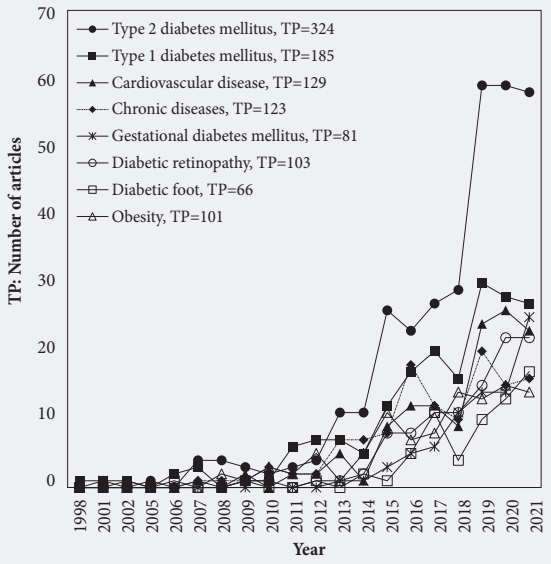
Finally, the research topic of "diabetic foot" describes a variety of complications related to the region of the foot in patients with diabetes. In addition to damaging blood vessels, high blood glucose levels can damage nerves in the feet, resulting in loss of sensation, wound infections, ulcers, and 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 the 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 |

*Source*: 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 patients with diabetes. Technology provides solutions to 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. 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 Keywords Plus, distributed by year of publication. This graph displays the main emphasis of technology research and its progression trends.

The research topic of "smartphones" (the 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, which are beneficial for facilitating the timely detection of diabetes.

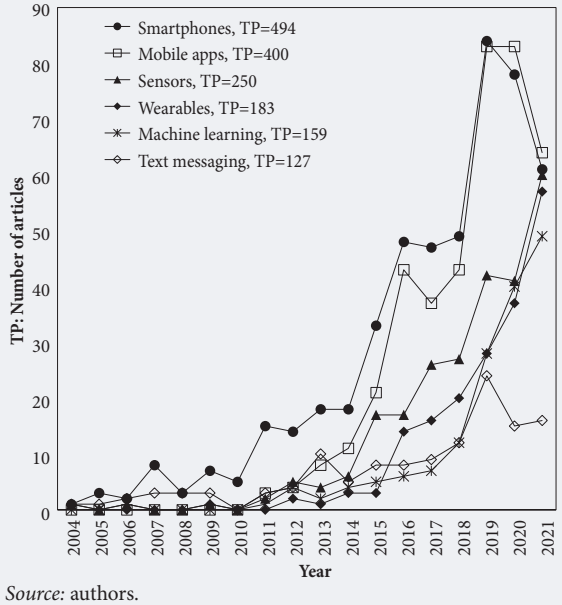
The research topic of "mobile apps" refers to software designed to run on mobile devices, such as smartphones, electronic tablets, and wearable devices, which provide a wide range of functions and services useful for healthcare services. There are 400 articles related to this topic. Notable advances 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-Ordonez 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, and motion. In healthcare, sensors are useful for monitoring vital signs, tracking physical activity and medication adherence, and detecting irregular behaviors. The number of articles associated with this topic is 250. Recent advances emphasize the integration of multiple sensors to obtain parameters in a non-invasive manner, providing timely warnings of 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 useful information 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 non-invasive glucose monitoring for diabetic patients.

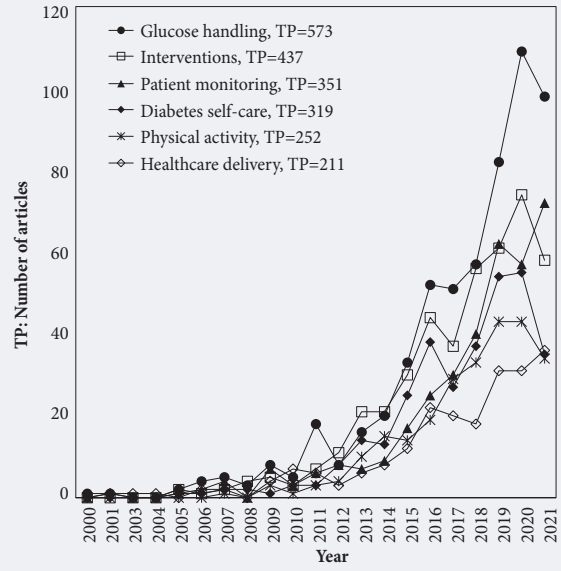
The research topic of "machine learning" covers computer algorithms that are trained to recognize and analyze patterns in large datasets for learning and decision-making activities to improve the performance of a task. Machine learning algorithms can be useful for analyzing data to determine diagnoses 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

Figure 3. **The Main research Topics and Their Development Trends in the Technologies Category**




*Source:* authors.

Figure 4. **The Main Research Topics and Their Development Trends in the Applications Category**




*Source:* authors.

the effectiveness of 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 non-invasive 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 and 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 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 Keywords Plus, the supporting words corresponding to each of the top six topics, distributed by year of publication. This graph allows for the identification of the focus in the applications category and its evolutionary trends.

The research topic "glucose handling" considers the context of the glucose control process, involving glucose detection, regular blood glucose testing, and the maintenance of blood sugar close to healthy levels. 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. Pustozerov 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 a 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 processes that enable the 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 the continuous measurement of vital parameters such as temperature, blood pressure, pulse, blood oxygen sat-

uration, and so on. 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 acquisition and collaborative participation with health professionals to develop self-management skills such as self-monitoring of glucose, consumption of healthy foods, regular exercise, adequate intake of medications, and constant monitoring of feet and eyes to avoid complications. 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 body movements that involve energy expenditure, such as exercise, walking, aerobic, and fitness activities. 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 older adults.

Finally, the research topic of "healthcare delivery" examines the provision of medical care to patients through interactions with healthcare professionals, such as consultations, medical services, recommendations, examinations, diagnoses, treatments, and procedures. The overall number of articles on this topic is 211. There have been advances in resolving communication challenges and providing remote alternatives for clinical consultations 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 accelerating diabetes dynamics that predict a 25% increase in the number of patients in 10-15-year increments (IDF, 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.

A word distribution analysis allowed for the identification of research topics on Diabetes mHealth for understanding their progress, which is useful for decision-making regarding 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 the most research topics was developed. Diabetes mHealth represents an innovative alternative for improving 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, furthmore, 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 smartphones, also known as mobile phones, 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 there is text messaging, which is useful for establishing communication between healthcare professionals and patients. Finally, machine learning, which helps identify patterns and make predictions based on large amounts of information. The 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 interactions- 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 healthcare professional services and reach the highest number of people; it provides solutions for remote locations where the number of healthcare professionals is low. 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 healthcare access for vulnerable populations. In addition, public health will be influenced by AI and IoT concerning 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, and 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 current knowledge on the 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 policymakers 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.

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# APPENDICES

Table A1. **Top 50 Most Frequently Used Terms in Titles, 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 on Health Problems with Their Supporting Words**

| Rank | Research topic | Supporting words from title, author keywords, and keywords plus | TS |
|---|---|---|---|
| | | ***Sub-category "Diseases"*** | |
| 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 |
| | | ***Sub-category "Diabetic complications"*** | |
| 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 |
| | | ***Sub-category "Risk factors"*** | |
| 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 |
| | | ***Sub-category "Complications"*** | |
| 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 on 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, mealtime, ersonalized, 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 1st | 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.