# The Application of Digital Health in Diabetes Management

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**Abstract.** Diabetes management is complex and multifarious as it contains numerous contexts including blood pressure and blood glucose monitoring, decision on daily insulin dose, strict diet, cautious planned exercises, and frequent clinical consultations. On the other hand, diabetes care requires patients' major efforts on self-management and initiative. Moreover, there are enormous amounts of data transition and sharing of electronic medical records, insulin pumps, sensors, glucometers, and such between patients with diabetes and healthcare professionals. Various digital health technologies have hence been developed to assist and supervise patients' daily diabetes management, in order to improve their medical adherence. Especially after the outbreak of COVID-19 pandemic, the era has witnessed a sudden growth of trend in applying digital health techniques in diabetes management. Increasingly, more patients with diabetes are using wearable or other technological devices to support diabetes self-management. Thus, this review article aims at conducting a horizontal comparison of current diabetes digital management in an international perspective, in order to provide some constructive suggestions on future research directions or references for improving diabetes tele-management in China in the post-pandemic era.

**Keywords:** Diabetes management, digital health, tele-management, telemedicine, glucose monitoring.

## 1. Introduction

The prevalence of diabetes mellitus has reached epidemic proportions globally and is recognized as one of the most daunting health issues in the 21st century (Marcolino et al., 2013). Adults[1] with diabetes account for approximately 537 million of the world's population, and the mortality rate caused by diabetes possessed a 3% increase in the previous decade (World Health Organization, 2022). According to IDF Diabetes Data Portal of 2021, China contributed the highest number of adults[1] with diabetes at 140,869.6(in 1000s), with the total annual medical expenditure for diabetes up to 611 billion RMB (Chinese yuan). Diabetes as one of the Chronic diseases, requires higher healthcare resources utilization and possess higher possibilities of worse health outcomes especially when consistent healthcare service is delayed or interrupted (Hajat & Stein, 2018). The four main aspects of diabetes management include blood sugar monitoring, oral diabetes medications, insulin, diets, and exercises (Cleveland Clinic, n.d.)

Besides, there are still several existing social problems in China, such as unbalanced allocation of medical resources between rural and urban areas, lack of access to healthcare services for people in remote districts, and old people with diabetes (PwDs) living alone without adequate surveillance. All of which initiate an urgent call for innovative and more effective ways to conduct diabetes management. However, the spread of COVID-19(coronavirus disease 2019) over the past three years had greatly changed the behaviors and habits in accessing healthcare, the application of health technologies and digital practices in health care had emerged at a numerous number (Ye, 2020). Digital health is mainly consist of four categories, as eHealth(Electronic Health), mHealth(Mobile Health), telehealth and telemedicine (Fatehi et al., 2020). Digitalization is revolutionizing the form of diabetes treatment, for its potential to empower systems to manage cost-effectiveness and improve utilization of medical resources (IDF Europe Symposium, 2022). The application of data is altering diabetes care and management, while changing the interactions between PwDs and healthcare

[1] Adults aged from 20 to 79.

professionals (HCPs) (IDF Europe Symposium, 2022). Yet, the barriers and ethical issues such as data access, privacy, and ownership, also arise with the rising usage of shared data.

Diabetes management is considered as a model for helping patients with chronic non-infectious diseases, resulting in a significant number of proposals in the digital market devoted to solving any problems associated with diabetes (Neborachko et al., 2019). Thus, understanding the mechanism of how to apply digital technologies appropriately in diabetes management will help later discover suitable modes of digital implementation in chronic disease. Herein, by analyzing and comparing the current implementations and features of digital health technologies in diabetes management globally2, it is aspired to understand advanced and experienced patterns in the world, in order to correspondingly improve tele-management in diabetes, as well as improve the quality and continuity of care for PwDs in China.

## 2. America

### 2.1 the Origin and Development of Telemedicine

As one of the most comprehensive areas of digital health, the development of telemedicine in America can tracked back to 1990s when the field was highly regarded, and allocations of state and federal for telemedicine and relative techniques were possibly to exceed up to 100 US dollars in fiscal (Perednia & Allen, 1995). In 1973, the first wearable infusion pump was created by Dean Kamen, who expanded upon the idea of the insulin pump; while in 1999, the first continuous glucose meter that collected data for 72 hours was approved by the FDA (U.S. Food and Drug Administration) (Acosta et al., 2019). In the same year, the Veterans Health Administration (VA) was an initial proponent of telemedicine nation-wide which adopted a chief telehealth officer dedicating to enhance access to care for a predominantly rural population of veterans with multimorbidity, including diabetes mellitus (Heyworth L, 2020). Multiple researches have shown that after the outbroke of COVID-19, the use of various virtual methods was highly leveraged including confidential email, telephone care, e-consults and video-to-home visits.

### 2.2 Current Implementations in Diabetes

For the purpose of enhancing a patient's health, telemedicine mainly operates through utilizing electronic shared data of medical information. In America, the existing measures of telemedicine applied in diabetes care are categorized into three sorts: synchronous telemedicine, which aims at providing real-time virtual care; asynchronous telemedicine, which requires access to health data and transmitted for analysis afterwards; remote monitoring, which gathers any constant and available data from patients, such as remote blood pressure monitor and continuous glucose monitor (Mullur et al., 2022). Scholars and researchers had summarized the telemedicine technologies in use and in pipeline targeting on the management of diabetes, including Blood Glucose Monitoring (BGM) Devices, insulin delivery devices, nutrition applications, and automated insulin delivery systems (Fleming et al., 2020; Ramchandani & Heptulla, 2012) (See Table 1). To better illustrate and compare between these devices, their advantages, disadvantages, and directions of improvements are listed in Table 2.

Table 1. Categories of Current Implementation of Telemedicine in USA.3

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[2] Gestational diabetes, juvenile diabetes (includes diabetes in infants, children, and adolescent), and other special populations with diabetes will not be discussed. Also, detailed comparisons of glucose monitoring systems or insulin injection methods in certain brands will not illustrate.

[3] Summary from *New Technologies for Diabetes: A Review of the Present and the Future*, by Ramchandani, Neesha.; Heptulla, Rubina A., 2012, International Journal of Pediatric Endocrinology, 28 (2012). Copyright by 2012, Ramchandani and Heptulla; licensee BioMed Central Ltd. Published by Springer Nature. And *A consensus report by the European Association for the Study of*

| Categories | Devices | Functions |
| --- | --- | --- |
| Blood Glucose Monitoring Devices | Capillary Blood Glucose Monitoring | Analyze through a glucose oxidase or a glucose dehydrogenase reaction. |
| | Continuous Glucose Monitoring | Continuous measurement of interstitial glucose concentrations. |
| Insulin delivery devices | Insulin Pumps | Allow user to enter carbohydrate intake and blood glucose and the pump calculates the insulin dose based on their settings. |
| | Smart Insulin | Releases insulin in response to glucose in the bloodstream. |
| | Insulin Titration Apps | Integrate bolus calculators with traditional blood glucose meters to calculate basal, prandial and correction insulin doses. |
| | Insulin Delivery Apps | For insulin pumps and smart pens to collect and display data, and provides decision support. |
| Nutrition Apps | - | Offering databases where users can track carbohydrate, fat, protein and energy content. |
| Automated Insulin Delivery systems | - | Also called 'closed-loop control systems', consists of a CGM system, insulin infusion pump, and a computer-controlled algorithm to allow communication between the CGM system and insulin pump on the patient. |

Table 2. The Feature and Directions of Improvement of Telemedicine Devices in USA.

| Devices | Advantages | Disadvantage s | Directions of Improvements | References |
| --- | --- | --- | --- | --- |
| Capillary Blood Glucose Monitorin g | (1)rograms insulin-to-carbohydrate ratio, correction factor, and target BG. (2)Enables wireless transmission of glucose values. (3)Connects to clinicians and caregivers. | (1)Subtle differences exist among meter performances . (2)Certain substances interfere with test strip accuracy. | Non-invasive glucose monitoring | (Ramchandani et al., 2011). |
| Continuou s Glucose Monitorin g | (1)Useful in identifying hypoglycemia in most conditions and daily glucose trends. | (1)Difficult to use regularly for extended periods. | (1)Develop smaller, more accurate devices. (2)Connecting CGM to insulin | (Bergenstal et al., 2011); (HP, 2008); (Ramchandani et al., 2011) |

*Diabetes (EASD) and the American Diabetes Association (ADA) Diabetes Technology Working Group*, by Fleming et al., 2020, Diabetologia 63, 229–241 (2020). Copyright by 2019, European Association for the Study of Diabetes and American Diabetes Association. Published by Springer Nature.

| | | | | |
|---|---|---|---|---|
| | (2)Better adherence to treatment in adults.<br>(3)Glycemic benefits of RT-CGM in all age groups.<br>(4)Connects to clinicians. | (2)Problematic equipment, insurance issues, and inaccuracy. | delivery, including closed-loop. | |
| Insulin Pumps | (1)Better glycemic control than multiple daily injections (MDI).<br>(2)Benefits the quality-of-life.<br>(3)Easy to use for all ages.<br>(4)Benefits in metabolism. | (1)Constant reminders.<br>(2)Less secure.<br>(3)May occur rapid onset of ketoacidosis. | (1)Becoming sensor-enhanced with easy-to-read output on the screen.<br>(2)Improving on the hardware to make it lighter and safer.<br>(3)Making pre-filled insulin cartridges.<br>(4)Improving on the size, interface, and usability. | (Doyle et al., 2004; Pickup & Renard, 2008);<br>( (Bode, Sabbah, et al., 2002; Bode, Tamborlane, et al., 2002);<br>(Maahs et al., 2010; Weinzimer, Ahern, et al., 2004; Weinzimer, Doyle, et al., 2004);<br>(Bergenstal et al., 2011) |
| Automated Insulin Delivery systems | (1)Improving the time spent in the person's desired blood sugar range decrease rates of low blood sugar,<br>or hypoglycemia.<br>(2)Safety and efficacy. | | | (Committee, 2021) |

## 2.3 Advantages and Limitations

### 2.3.1 Advantages

In the overall perspective, Mullur stated that remote monitoring of glucose level could lead to improved HbA1c levels in individuals with insufficient glucose control, which also enabled the transmission of real-time blood glucose to the healthcare providers in order to reach the early surveillance of diabetes self-management and any possible problems (Mullur et al., 2022). As research proved that continuous glucose monitoring, a real-time device measures interstitial fluid glucose with subcutaneous sensors and delivers output information of glucose levels and trends to the patient, is evidently more effective in providing insulin dosing information, early alerts, and more secure and high-utilized management than Self-monitoring of blood glucose (SMBG) (Karter et al., 2021). Furthermore, some scholars propound a novel system combing BGM system, SMBG system and FSBG (finger-stick blood glucose monitoring) system, which has been proved that adults with uncontrolled Type 2 diabetes mellitus(T2DM) achieved pronounced HbA1c improvement with less frequent use of FSBGs (Montero et al., 2021).

### 2.3.2 Limitations

While the remote technology has achieved certain efforts in diabetes treatment and management, some modifications and adjustments are required in particular aspects. For any form of telemedicine application, the combination of remote consultations and remote monitoring is essential to the assessment of glycemic control and therapy adjustments, the position of diabetes educators coordinating with primary cares and intime remote follow-up tracking is greatly emphasized in daily diabetes self-managements (Carlson et al., 2021). Additionally, the cost-effectiveness of the intervention should also be considered on the foundation of indiscrimination between physicians and nurses if includes the applications in healthcare system (Marcolino et al., 2013). Marcolino also stated the importance of senior-friendly adjustment in the consequence of T2DM is more common in older patients who have lower rate of technology use and greater anxiety using intelligent devices. Some scholars also point out that certain clinical conditions, such as pregnancy, hemoglobinopathies, erythrocyte turnover disorders, and renal insufficiency, can result in an incorrectness of HbA1c level.

## 3. Europe

### 3.1 the Sudden Growth of Telemedicine

The COVID-19 pandemic and the urgent need of medical service's digitalization has brought great challenges and pressure to European medical sectors, which emphasizes the importance of introducing technology in health processes to maintain and extend the sustainability and resilience of healthcare systems (Ţăran et al., 2022). By the end of 2021, the total statistics of living diabetic patients has risen up to 61 million, and 189 billion USD were spent on diabetes (IDF, 2021). Experts agree the statement that routine clinical practice may be replaced by a transformation towards telemedicine by 2030 (John, 2020).

### 3.2 Current Implementations in Diabetes

In the past decades, both America and Europe are the major leading trends of diabetes technology development in a global scale. Although the regulatory and approval procedures in the two locations vary slightly, the newly-invented products enter the market at comparable timepoints (Acosta et al., 2019). Furthermore, the past time has seen the cooperation and collaboration between these two locations in research and other aspects, such as consensus reports by ADA(the American Diabetes Association) and EASD(the European Association for the Study of Diabetes) (Chung et al., 2020; Davies et al., 2022; Davies et al., 2018; Fleming et al., 2020; Holt et al., 2021).

Thus, the condition of current diabetes technology possesses many similarities between America and Europe. Additionally, it is illustrated that the diabetes technology currently available in USA and Europe includes digital insulin pens, CGM systems, and insulin pumps (Acosta et al., 2019). It can also be seen from the research (Acosta et al., 2019) that the availability of types and brands of these technological devices in two locations is also different. The digital health applied in diabetes care in Europe can mainly been classified in four categories (See Table 3) (Choudhary et al., 2021).

Table 3. Categories of Digital Health in Diabetes Care in Europe.[4]

| Categories | Description | Examples |
|---|---|---|
| eHealth | Electronic health, the cost-effective and secure use of information and | Healthcare services, health surveillance, health literature |

[4] Summary from *The Challenge of Sustainable Access to Telemonitoring Tools for People with Diabetes in Europe: Lessons from COVID-19 and Beyond*, by Choudhary et al., 2021, Diabetes Therapy, 12, 2311–2327 (2021). Copyright 2021 by The Author(s). Published by Springer Nature.

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|---|---|---|
| | communication technologies in support of health and health-related fields. | and health education, knowledge and research. |
| mHealth | Mobile health is a subsegment of eHealth by which medical and public health practices are directly supported by mobile devices. Including the use of mobile communications devices for delivering health and well-being information and services, as well as mobile health applications. | Smartphone apps for reading and reporting glucose-sensor data are established examples of mHealth. |
| Telemedicine | The practice of medicine using technology to deliver care at a distance, whereby an HCP in one location uses a telecommunications infrastructure to deliver medical care to a patient at a distant site, involving synchronous or asynchronous types. | Telemonitoring (see below), tele-expertise, tele-assistance, tele-visit, teleconsultation and tele-education. |
| Telemonitoring | The use of information and communication technology to monitor, transmit and share information between geographically separated individuals that relates to the health status of a patient. | The use of CGM systems to monitor glycemic metrics is an example of telemonitoring. |

### 3.3 Advantages and Limitations

#### 3.3.1 Advantages

In Europe, extensive researches have evidenced the significant advantages in reducing HbA1c levels and hypoglycemia of CGM or flash glucose monitoring in T1DM(Type 1 diabetes mellitus) or T2DM (Aleppo et al., 2017; Beck, Riddlesworth, Ruedy, Ahmann, Bergenstal, et al., 2017; Beck, Riddlesworth, Ruedy, Ahmann, Haller, et al., 2017; Bolinder et al., 2016; Evans et al., 2020; Haak et al., 2017; Kröger et al., 2020; Lind et al., 2017). Studies on tracking the efficiency of FreeStyle Libre system used among T1DM and T2DM patients before and during COVID-19 in Scotland (Dover et al., 2021), Spain (Fernández et al., 2020) and France (Potier et al., 2021), has respectively shown improvements in glycemic variability and HbA1c as well as diminishments in average glucose level. Nevertheless, comparison in the optimality of glycemic control in time in range between real-time (rtCGM) and intermittently scanned (isCGM, FreeStyle Libre as example) continuous glucose monitoring was conducted among T1DM adult patients, which resulted that rtCGM showed an advance in reducing the occurrence of hypoglycemia during exercise and daily diabetes self-management for its in-time alarms (Hásková et al., 2020).

#### 3.3.2 Limitations

Lum and others' study in 2018 highlighted the necessity of quality control systems for diabetes applications to help individuals with diabetes, as the most system lacked real-time decision guidance or individualized blood glucose self-management instruction (Lum et al., 2019). For example, the system should be designed more age-friendly according to different target age groups. It is also addressed by Landau and others that although FreeStyle Libre possesses shorter replacement intervals and non-required calibration, it has no alarms of imminent hypoglycemia or hyperglycemia (Landau et al., 2018). Thus, more efforts should be laid on ensuring patients' security with improving the accuracy, clinical validity and quality of mobile health apps. Another factor to take into account is the uniformity of language and presentation such as blood sugar, time in range, standard deviation, BMI, e stablishing standards for information presentation would decrease translation and interpretation mistakes from app to HCP to patient (Fleming et al., 2020).

## 4. Low-income and Middle-income Countries

### 4.1 Facing Problems

Seen from an overall perspective, the burden of diabetes with increasing prevalence rate was more prominent in low-income and middle-income countries (LMICs) than that in high-income countries (Zhou et al., 2016). The statement was discussed in details in several reports that the similar upcoming increases in disease rate in China (Li et al., 2013; Zuo et al., 2014), India (Jayawardena et al., 2012; Misra et al., 2011; Mohan et al., 2006; Ramachandran et al., 2012), and Saudi Arabia (Alharbi et al., 2014).

Based on the heavy disease burden, a study suggested whether telehealth technology such as CGM system in diabetes will be effective should consider the resource settings, based on the fact that the timeline of new technology introduction into LMICs may be delayed and may be prohibitively expensive to implement in the early stages (Gupta et al., 2023). Additionally, in non-Western countries, vascular complications and inadequate glycemic control were greatly related to healthcare resource usage (Gagliardino et al., 2017). It is also suggested that the quality of healthcare services and the equity of distribution of medical resources are unassured especially in LMICs, resulting in poor access to medical services and major gap in medical services delivery for those with heavy burden of disease (Bhattacharyya et al., 2010).

### 4.2 Current Implementations in Diabetes

Notably, several diabetes-related digital health practices have been undertaken in LMICs. A review included various tele-based diabetic management interventions, yet these measures mainly conducted through smartphone apps, SMS messages, telemetry, telephone and web-based systems such as video conferences, indicating that most research about this field in LMICs mainly focused on a single mode (Correia et al., 2021). India and Saudi Arabia as two typical low-income and middle-income countries which have been carrying out trials on implementing diabetes digital health or relative technologies, they will be discussed in priority.

#### 4.2.1 India

A consensus guideline estimated in 2019 in India pointed out that, the evaluation of glucose metabolic disruption, assessment to the effectiveness of treatment, and direct modifications to therapies were all mainly dependent on the outcomes of BGM (Chawla et al., 2019). Nevertheless, still being the most common choice of domestic BGM, SMBG showed its frequent failure in providing adequate warnings to upcoming hypoglycemia or hyperglycemia (Chawla et al., 2019). It was also reported that the contents and formats of CGM reports are lack of unification, although it was proved better achievement in improving HbA1C levels and accomplishing glycemic goals than traditional therapies. Additionally, due to the certain impacts brought by Indian Ramadan on insulin and hypoglycemia, a study had researched on the effect of telemonitoring during Ramadan and it was proved a useful adjunct with no deterioration in glycemic control (Lee et al., 2017).

#### 4.2.2 Saudi Arabia

The structure and system of telemedicine implementation in Saudi Arabia is relatively integral than other LMICs. In the report conducted in King Saud University Medical City, Saudi Arabia, it introduced their protocol, experience and effect of rapid implementation of diabetes telemedicine (Al-Sofiani et al., 2020). Its framework of diabetes telemedicine clinic protocol mainly requires seven basic sections, including technical requirements, online patient request form, scheduling the visits, setting up the virtual visit, delivery of the medications and supply, virtual ‘Diabetes and Ramadan’ educational sessions, and patients’ and HCPs’ satisfaction surveys (see Figure 2). Notably, because of the religious culture of Muslim in Saudi Arabia, there are extra educations and guidelines according to the diabetes self-management during Ramadan.

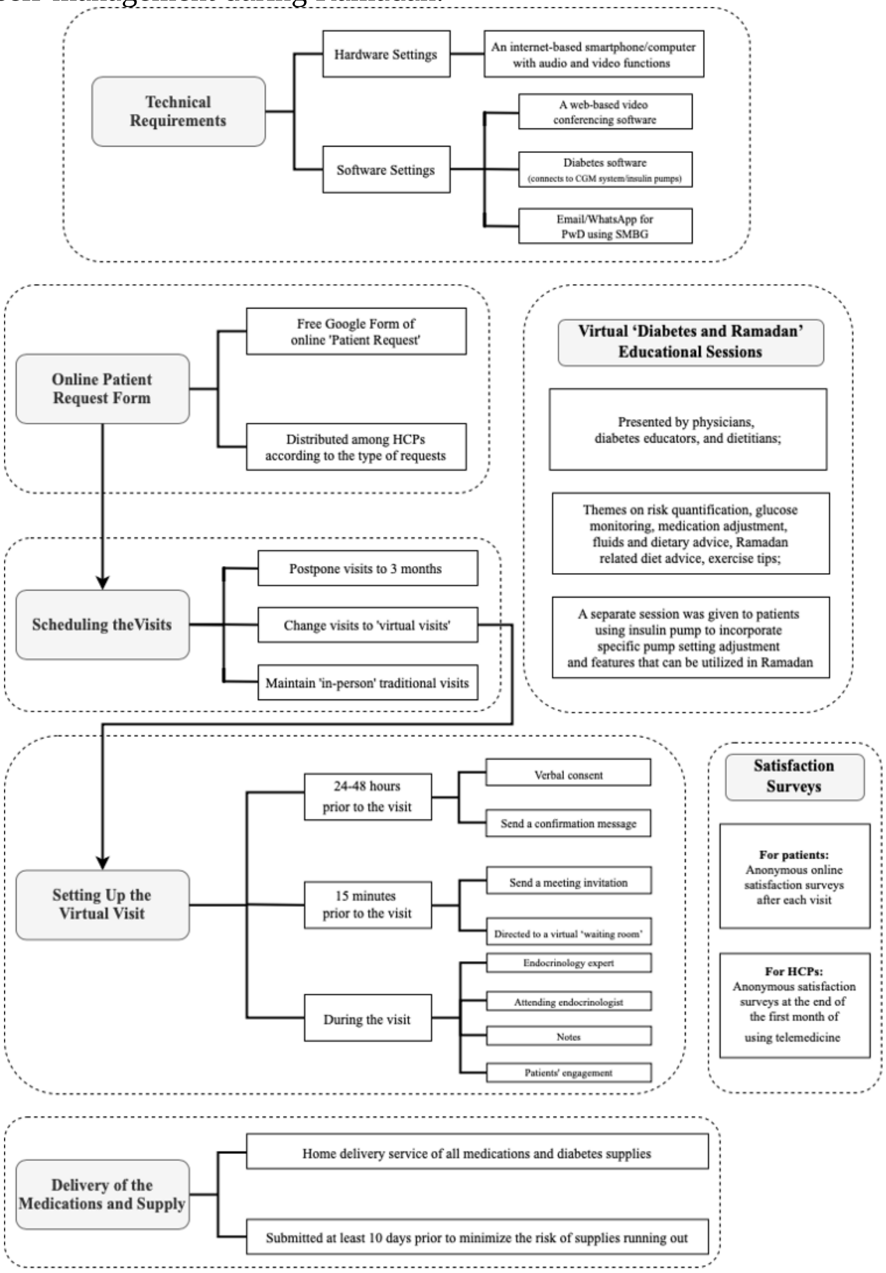


Figure 1. Diabetes Telemedicine Clinic Protocol in Saudi Arabia5.

## 5. China

### 5.1 Barriers and Problems

A significant problem in medical resources utilization in China is the sever imbalance distribution of medical resources between rural areas and urban areas (Anand et al., 2008). Thus, China has massively expanded financial investment and implemented favorable policies to strengthen its primary health care system, which is responsible for preventing and controlling chronic diseases as well as emerging infectious diseases such as COVID-19 (Li et al., 2020). One of the recommendations includes establishing a smart health system based on digital data and innovative technologies. As a

[5] Summary from *Rapid Implementation of a Diabetes Telemedicine Clinic During the Coronavirus Disease 2019 Outbreak: Our Protocol, Experience, and Satisfaction Reports in Saudi Arabia*, by Al-Sofiani et al., 2021, Journal of Diabetes Science and Technology, 15(2):329-338. Copyright by 2020 Diabetes Technology Society.

result, telemedicine has been employed as a significant tool for medical reform, and many policies have been enacted to promote the growth of telemedicine in China (Cui et al., 2020).

A resident survey has conducted in China, with the result of the utilization rate of Internet-based healthcare services offered by primary healthcare institutions had reached over more than half, and most of the users possessed a considerable satisfaction, albeit there were substantial disparities between subgroups (Wang et al., 2022). It was addressed in another cross-sectional survey among Chinese medical professionals, medical students and patients that the majority had a high awareness of telehealth (mainly traditional forms of telemedicine), yet only a marginal proportion adopted in practice (Chen et al., 2017). Therefore, in the current period, telemedicine is still in starting stage and under systematic development in China.

### 5.2 Current Implementations in Diabetes

In the *Expert Consensus on Telemedicine Management of Diabetes (2020 Edition),* the current framework of telemedicine management in diabetes was clearly illustrated (See Figure 3) (Zhang, 2021). The consensus discussed the scenarios and PwDs which are suitable for telemedicine management, the types of telemedicine technologies in use (see Table 4), education and behavior management, and dietary management. It was also stated that telemedicine management is suitable for conducting comprehensive assessment and regular telemonitoring, health education, individualized visual dietary and exercise guidance, efficacy assessment of PwD, and follow-up visits.

As for the telemedicine technologies currently in use in China, glucose monitoring is regarded as an important method to evaluate the glucose level and the effectiveness of therapies in China (Bao et al., 2022). The most adopted glucose monitoring systems in China include capillary glucose monitoring system (which includes SMBG) and CGM system. In addition, there are three types of insulin pumps currently used in China, involving traditional insulin pumps, sensor-augmented insulin pumps, and catherter-less insulin pumps (Association, 2021). The *Guidelines for Insulin Pump Therapy in China* had also indicated the clear instruction of choosing suitable insulin, initial dose setting (such as total daily dose and defined daily dose) according to the needs of different PwDs.

**Certification: the certification should be approved by the National Center for Chronic Disease Telemedicine and related health departments.*

**Telemedicine Technologies: the detail information is listed in Table 4.*

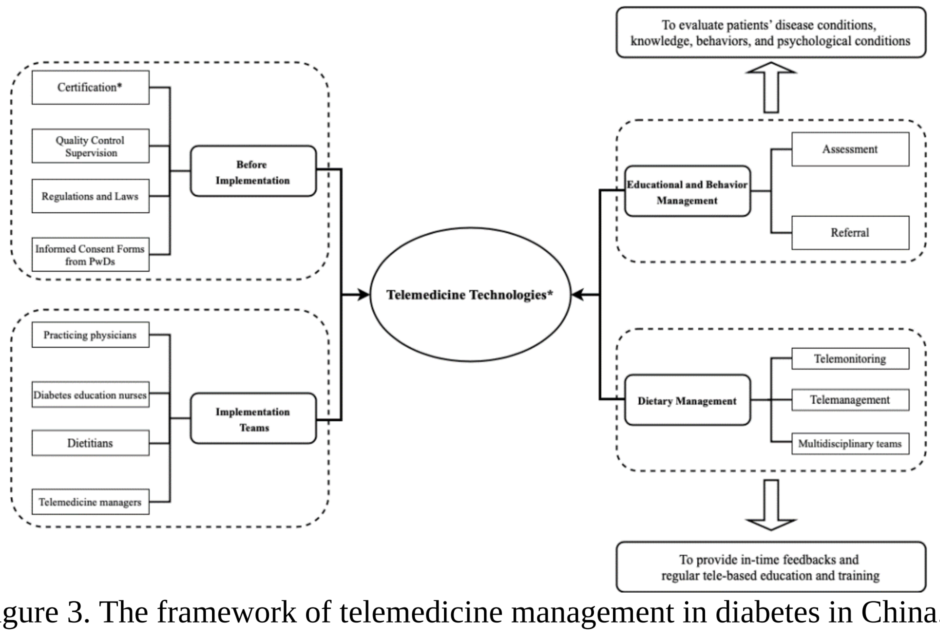


Figure 3. The framework of telemedicine management in diabetes in China.6

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6 Summary from Zhang, B. (2021). Expert Consensus on Telemedicine Management of Diabetes (2020 Edition). *International*

Table 4. The types of telemedicine technologies in use in China. 7

| Categories | Devices | References |
|---|---|---|
| Glucose Monitoring Systems | Capillary Glucose Monitoring<br>Self-monitoring of Blood Glucose<br>Continuous Glucose Monitoring | (Bao et al., 2022) |
| Insulin Pumps | Traditional Insulin Pumps<br>Sensor-augmented Insulin Pumps<br>Catherter-less Insulin Pumps | (Association, 2021) |

### 5.3 Advantages and Limitations

Capillary glucose monitoring is the most fundamental and effective method for daily management, which can reflect real-time glucose levels as well as detect life events such as diet, exercise, mood, stress, and etc. However, it was evidenced that there were slight differences of the result compared to venous glucose levels (Demir et al., 2008). Furthermore, capillary glucose monitoring is not suggested in following clinical circumstances involving microcirculatory obstruction at the blood sample site, such as shock, severe hypotension, diabetic ketoacidosis, hyperglycemic hyperosmolar states, severe dehydration, and oedema, and others (Bao et al., 2022). For CGM devices, there are three types in use currently, including retrospective CGM, real-time CGM (rtCGM), and flash glucose monitoring (FGM). There is no absolute advantages among those three types of systems, however, it is notable that CGM remains relatively price-exorbitant, despite previous reports showing CGM is more cost-effective than SMBG in insulin-treated patients with T1DM or T2DM (Bilir et al., 2018; García-Lorenzo et al., 2018; Roze et al., 2020).

## 6. Suggestions for Future Development in China

It can be seen that America and European countries are still the pioneers in the field of telemedicine, while the development in LMICs is comparatively behindhand. Whereas among the developing countries the implementing systems in Saudi Arabia and India are somewhat more complete than the others. Therefore, to learn from previous experiences from other countries or district and to consider further prompting diabetes tele-management in China.

### 6.1 Building modernized system of infrastructure

Infrastructure, as the configuration for hardware equipment, is undoubtedly one of the main preconditions which provides the fundamental support for all kinds of digital health devices. The major difference of the speed of development in digital health between western countries(i.e. USA and Europe mentioned above) and LMICs is the level of construction in hardware settings. It is still notable that the inequality of development between rural areas and urban areas is significant in China (Park, 2008), which sharpens the unbalanced distribution of medical resources between two districts. To ease the tension of health resilience and uneven medical resources between rural and urban areas, meanwhile to speed up the development of digital health technologies in rural areas, the priority is to optimize the construction of infrastructure in villages. By this way, digital health will better enhance the access of healthcare services for PwDs in rural areas and compensate the healthcare gaps.

### 6.2 Improving the techniques of digital health

There are still rising problems as lack of continuous record tracking, data security, privacy protection, expenses, and risk management in the field of digital health (Zhang, 2021). Recent research has exposed concerns on the inadequate eHealth literacy in populations in spite of numerous attempts have been applied to ensure proper translation, knowledge refinement, and fact-checking during use (Liu & Xiao, 2021). Additionally, privacy and security issues emerged in the settings of

*Journal of Endocrinology*, *2021*, 6643491. https://doi.org/10.1155/2021/6643491 digital health were also worrying (Filkins et al., 2016). Emergency response mechanisms need to be set and activated when devices come across with the situations of no internet-connections or out of batteries. Furthermore, to build a more comprehensive and flexible system of diabetes tele-management, close-knit connections between devices and systems, PwDs' health data shared from tertiary hospitals and primary healthcare institutions should be encouraged. Yet, the privacy principles should be well guaranteed from hacks attacks or information leaks during the data-sharing process. Therefore, how to identify and process the information on digital devices, ensure security and privacy for PwDs, create an intellective operation mechanism when providing diabetes-related digital healthcare services accurately will be a prior developing mission. The previous experiences from USA and Europe have offered good directions for the future improvement in techniques of diabetes technology.

### 6.3 Expanding the targeted beneficiary populations

Although the considerable advantages of digital health technologies are promising, there are still a significant number of populations who have not yet enjoyed the convenience that digital health brought (Wiwatkunupakarn et al., 2023). For example, PwDs who are at poor financial conditions, low level of education, senior ages, or with disabilities. Previous studies showed that telemedicine interventions are harder to conduct among older diabetic patients, yet they tend to prefer smart devices with user-friendly interface (Sun et al., 2019). In addition, educational level or individuals' quality also influences the clinical outcomes of diabetes telemedicine (Wu et al., 2018). Adjusting the programs according to patients in different age groups (such as younger users or senior users) will improve medical outcomes among PwDs, while also avoid inappropriate use and inconvenience (Kruse et al., 2020). To improve the quality of medical outcomes and expand the beneficiary groups in diabetes tele-management, may require the devices or systems designers to consider more efforts in inclusiveness and suitability for wider range of populations. According to the emerging problems, experts advised building a more accurate and comprehensive diabetes tele-education system (Zhang, 2021).

## 7. Conclusion

The framework of diabetes digital management in China has already presented in a contemporarily developed and relatively systematic pattern. Nevertheless, the details of implementation still require perfections and meanwhile the gap in techniques of devices' need to be narrowed. This article listed and compared the current status of digital health in diabetes management in USA, Europe, LMICs, and China, which provides certain inspirations and references for the future development of diabetes tele-management in China. Nevertheless, there are some limitations in this article, such as the mentioned implementations of these countries or districts are not comprehensive, and the situation of special populations with diabetes is not discussed.

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