

Smartphone-Based Glucose Monitors and Applications in the Management of Diabetes: An Overview of 10 Salient “Apps” and a Novel Smartphone-Connected Blood Glucose Monitor

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According to the American Diabetes Association, the direct and indirect costs of diabetes in the United States have exceeded \$174 billion, and there are 25.8 million U.S. children and adults with diabetes.¹ Numerous resources are available to help patients increase their role in the management of diabetes while simultaneously improving their metabolic parameters. Although the Internet is a burgeoning source of information and resources, the average patient often lacks the skills for finding and using the most optimal health care information.²

It is important for health care providers (HCPs) to educate patients about the available pragmatic technological resources for the management of their diabetes. Specifically, smartphones have become an integral component of daily life for many people in the United States. In 2011, > 85% of Americans owned and used a mobile phone, and half of those users also had Internet access with their mobile devices.³ The implementation of smartphone applications and tools for the management of diabetes may be an effective option in reducing the progression of diabetes and improving quality of life.

Consistent self-monitoring blood glucose (SMBG) has been shown to be a useful tool in improving glycemic control in type 2 diabetes.⁴

The use of smartphone applications (“apps”) has already been shown to be a useful method for accurately logging and managing SMBG results. SMBG data that are logged on a smartphone app can be easily reviewed with HCPs to make recommendations about exercise, diet, or medications. A meta-analysis revealed that using SMBG data stored in and/or shared through a PDA (personal data assistant), logbook, the Internet, fax machines, and other innovative technologies, along with consistent feedback from an HCP, enhanced glycemic improvements and reduced hospitalizations.⁵

The goal of using smartphone apps is to effectively manage diabetes by improving glycemic control and, ultimately, preventing or delaying further complications of diabetes.⁶ Smartphones or devices such as the iPod Touch and the iPad (sometimes referred to as “iOS devices” for their operating system) offer a variety of diabetes apps that also may be helpful in the management of other aspects of diabetes care such as exercise, carbohydrate counting, and medication adherence.

This article provides a cursory review of 10 salient, easy-to-use smartphone apps that may be useful to patients with diabetes. These applications were chosen by the authors based on their utility and

ease of use. It should be noted, however, that there are many more potentially useful available apps not included in this review. We also review a new SMBG technology integrated directly into a smartphone (iBGstar, Sanofi Diabetes, Bridgewater, NJ).

Proven Utility of Apps

Several studies have evaluated the use of smartphones in the management of diabetes. One study⁶ analyzed the evolution of data management tools for managing SMBG using iPhone apps. Apps were reviewed based on a series of criteria, including glucose, carbohydrate, and insulin data, as well as hypoglycemia and hyperglycemia events. Analyzed apps included Diabetes Logbook, Blood Sugar Diabetes Control, and WaveSense Diabetes Manager. Selected participants were observed and given a written questionnaire to complete for each of the apps. The results showed that WaveSense Diabetes Manager enabled participants to input pre-selected SMBG values and perform tasks faster than the other apps. The study concluded that the ability to record, analyze, and concurrently share and obtain feedback on SMBG data using an iPad or iPod Touch may potentially benefit patients.

Another review of the use of apps⁷ was based on a meta-analysis of studies that analyzed the use of

mobile phones for diabetes self-management and its impact on A1C. The authors searched electronic databases including Pubmed, EMBASE, and the Cochrane Library and identified and evaluated 22 articles with regard to the effects of smartphones on A1C. Although the methods of smartphone intervention were diverse in their approach to reinforcing lifestyle change, healthy diets, and exercise, the pooled difference in A1C was a 0.5% reduction compared to control groups in both type 1 or type 2 diabetic patients. In subgroup analysis, patients with type 2 diabetes reported a greater A1C reduction (0.8%, $P = 0.02$) than patients with type 1 diabetes (0.3%, $P = 0.02$). These results suggest that the use of mobile phones leads to improved A1C and self-management in diabetes care.

Review of Apps

This section offers brief reviews of 10 diabetes-related smartphone apps. Information about these apps is summarized in Table 1.

Diabetes Buddy

With its sleek, modern layout and strong contrasting colors, Diabetes Buddy⁸ (Krodzone Technologies) is tastefully designed and allows users to log diabetes-related data values in only a few keystrokes (Figure 1). The app's overview section shows a monthly calendar on which daily logs are displayed. Users can record glucose values, physical activity time, carbohydrate intake, and water consumption.

Diabetes Buddy and TRACK3, another app discussed below, have a similar food database. However, Diabetes Buddy has an additional function that allows users to add personalized recipes. The carbohydrate content for the entire recipe is then broken down per ingredient. The carbohydrate log section

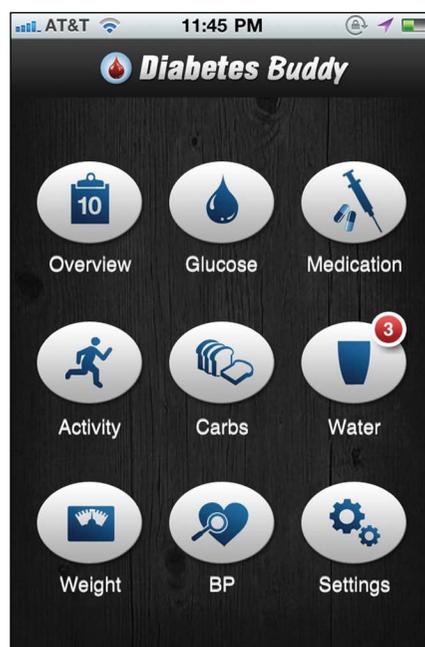


Figure 1. *Diabetes Buddy* app.

displays the total daily grams of carbohydrate consumed and remaining grams of carbohydrate available based on logged food items. In the same section, the app also displays other daily nutritional data, including the total amounts of calories, fiber, sugar, and protein consumed.

Overall, Diabetes Buddy excels in its logging capacity but could be enhanced with an alarm reminder for blood glucose readings and medication intake. Recorded data can be sent through e-mail, but an external spreadsheet software is required for the receiver to open and evaluate it. Diabetes Buddy could benefit from an organized table that automatically displays all of the logs directly in the e-mail. Still, it is a reasonably useful app.

Diabetes Log

The developers of Diabetes Log⁹ (Distal Thoughts) sought to create an app that is succinct without the extra features that may confuse users who are new to electronic data tracking. This app provides a logical and easy-to-use approach to logging data. It

features three options: glucose, food, and medicine.

Given its goal of simplicity of use, Diabetes Log would be improved by offering automatic synchronization of patients' data values to HCPs' offices for continual monitoring recommendations. Nonetheless, this app may be valuable to patients who are new to smartphone technology.

Diabetes Pilot

Diabetes Pilot¹⁰ (Digital Altitudes) contains the essential logging features in addition to a comprehensive database that includes nutritional information on thousands of food items. It also contains information about carbohydrate, fat, protein, fiber, sodium, cholesterol, and other nutrients. There is a useful logbook to record and monitor medication intake, food, weight, and blood glucose averages for 7, 30, 60, and 90 days. This app also offers an insulin calculator that takes into account the fiber, protein, and carbohydrate content of foods entered for a meal and calculates the number of insulin units required to reach a targeted blood glucose value.

Two drawbacks of this app are that there are additional costs to purchase the software needed to synchronize recorded data and food information to a computer, and the insulin calculator does not consider additional factors such as exercise, previous dose, or other causes that could affect the amount of insulin needed. Thus, this function of the app should be used with caution and with this limitation in mind.

Diamedic

Diamedic¹¹ (Nicholas Martin) is especially useful for patients with type 1 diabetes because of its capacity to track basal program settings for insulin pumps and ability to calculate corrective and mealtime insulin doses. It offers an assortment of graphs and

Table 1. Summary of Features on 10 Smartphone Apps for Diabetes Self-Management

Name	Diabetes Buddy	Diabetes Log	Diabetes Pilot	Diamedic	Glucose Buddy	iDiabetes	LogFrog	TRACK3	WaveSense Diabetes Manager	Your Diabetes Diary
Price	\$6.99	Free	\$14.99	\$3.99	Free	\$1.99	\$2.99	\$4.99	Free	\$4.99
Features										
Usability	Easy	Easy	Easy	Easy	Easy	Mediocre	Easy	Easy	Easy	Easy
Glucose tracking	x	x	x	x	x	x	x	x	x	x
Color-coded for hyper- and hypoglycemia				x	x			x	x	
Medication alarm					x		x			
Insulin tracking	x	x	x	x	x		x	x	x	x
Carbohydrate tracking	x	x	x	x	x		x	x	x	x
Activity tracking	x		x	x	x		x	x		x
Weight tracking	x		x	x			x	x		x
Blood pressure tracking	x		x	x			x			x
Meal tagging*	x		x		x			x	x	
Food database	x		x		~			x		
Note taking	x	x	x	x	x	x	x	x	x	x
Trend charts	x		x	x	x	x	x	x	x	x
GoogleDoc synchronizing							x			
Medical exam notes				x			x			x
Landscape mode			x				x		x	x
Logbook view		x	x	x	x	x	x			x
Averages	x		x	x	x		x	x	x	x
Electronic synchronizing with HCP		x	x	x	x	x	x	x	x	x

*Meal tagging is a feature similar to Facebook tagging that allows users to search a food database for specific meals by brand, categories, or restaurant names.

charts such as histograms, scatter plots, and pie charts to view weekly blood glucose readings. There are also scatter-plot graphs to view weekly trends in A1C, insulin units, carbohydrate intake, weight, and pulse changes.

Unfortunately, the medication logbook contains a set list of diabetes and cholesterol-lowering medications, and adding other medications is not feasible.

Glucose Buddy

This app¹² (SkyHealth) can guide any patient through the activities of recording and monitoring glucose, medications, carbohydrate intake, and A1C and enables data to be easily synchronized online to the Glucose Buddy's Web site. One distinct feature is its ability to give reminders, which can be tailored to user preferences. For example, it can remind users to check their blood glucose and take their medication at specific time intervals.

Glucose Buddy also incorporates social media such as Facebook and Twitter to communicate to users about updates and changes to the app. There is also an online forum enabling users to share their experiences and have questions answered from others regarding topics such as insulin pumps or gestational diabetes.

Limitations of this app include a \$3.99 fee to enable blood pressure and weight logging. For the effective management of daily carbohydrate intake, a separate app called CalorieTrack is required in addition to Glucose Buddy. This app is convenient to use, but it is still in the early stages of development, and some operating issues remain to be resolved.

iDiabetes

iDiabetes¹³ (iHealthVentures) is a simple app that is solely used to

record blood glucose values. One convenient aspect of it is its ability to e-mail HCPs with the logged blood glucose data.

However, the app's format is limited when logging blood glucose values because of it lacks a specific section in which to record each diabetes-related medication. The medication list provided includes only injectable medications and does not include oral diabetes agents, although there is an option to manually log medications that are not listed. Additionally, there are no instructions about how to use the app; the only available customer assistance is through e-mail.

LogFrog DB

LogFrog¹⁴ (Amphistyle) is one of the most versatile diabetes apps available and can be easily used by both young children and adults (Figure 2).

Of the apps reviewed here, it is one of the easiest to navigate. The instructions to review the app are concise and simply accessed by tapping the frog animation on the main screen. There is also an interactive pinwheel containing multiple categories, and specific data are stored by spinning the pinwheel. The categories on the pinwheel are depicted through icons instead of words. For example, there are 24 exercise routines demonstrated by stick figures performing each activity. In addition, recorded data can be exported to e-mail or Google documents in a colorful, organized table.

Unique features of this app include specific sections for logging comprehensive medical examinations, including eye, foot, and dental exam results, laboratory values, and even electrocardiogram and X-ray findings. Average blood glucose can be viewed for 7, 30, or 90 days.

One limitation is that there is no integrated food database, which would be helpful in obtain-

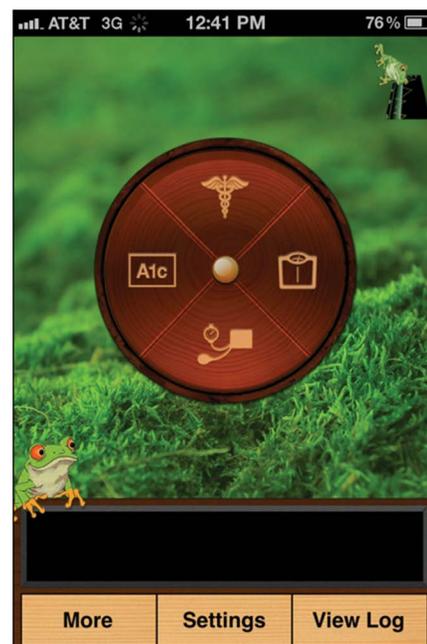


Figure 2. LogFrog DB app.

ing information about the nutrition and carbohydrate content of various foods. Also, the icons on the pinwheel are small and may be difficult for some viewers to read.

TRACK3

TRACK3¹⁵ (Coheso) is available in both the iTunes Store and Android Market. This app is intended for users who are more concerned about managing meals and exercise activity. It offers a food database that includes an extensive list of restaurant menus and brands of packaged foods, along with their nutritional contents. Specific nutritional content can easily be saved into a favorites section, making it more convenient for users to log the foods they regularly eat.

The app also allows users to create a food journal and to share it with their HCPs. It also offers a comprehensive list of exercise activities that can be logged, ranging from ballroom dancing to different degrees of aerobic exercises.

TRACK3 includes an insulin calculator that determines the amount of insulin doses, taking into con-

sideration users' correction factors and insulin-to-carbohydrate ratios. It also provides a designated section where users can directly e-mail questions to their product support team.

WaveSense Diabetes Manager

In a 2010 review of diabetes data management tools available at that time, Ciemins et al.¹⁶ rated WaveSense Diabetes Manager¹⁷ (AgaMatrix) (Figure 3) as the easiest, fastest, and most trustworthy app, with the fewest requests for help. In the realm of free apps, WaveSense continues to rank high in usability, convenience of data charts, and overall design.

WaveSense has a personalization feature that allows users to select from different wallpapers, enhancing its usability and visual appeal. A partnership with dLife, an online diabetes resource, provides educational videos about living with diabetes covering topics such as athletes with diabetes, recipes, and health.

Overall, WaveSense delivers an effective package for data monitoring and provides useful charts and comprehensive health information. However, although very easy to use, this app lacks the capability for logging nondiabetes medications, blood pressure, or weight and does not include an alarm function as a medication or SMBG reminder.

Your Diabetes Diary

People with diabetes can use Your Diabetes Diary¹⁸ (Leichhardt) in conjunction with their HCP. It has an HCP version, as well as a separate guardian version (allows a parent or guardian to monitor). This feature enables HCPs and guardians to have access to all entries made by the patients who use it. A variety of specific parameters such as cholesterol, BMI, creatinine, and results of dental and foot exams can be logged and monitored through graphs.

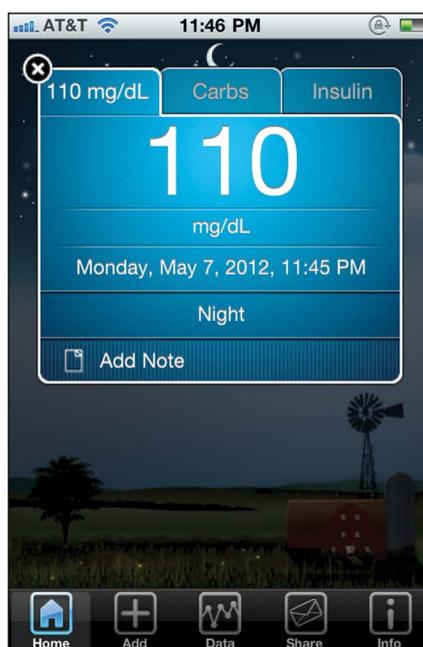


Figure 3. WaveSense Diabetes Manager app.

One drawback is that the extensive user guide can be time-consuming when users are learning how to navigate the app. Still, this product may be effective in cases where bidirectional access is a consideration.

New and Emerging Technologies

iBGStar

As the market for diabetes apps grows, novel technologies continue to emerge. The U.S. Food and Drug Administration recently approved an innovative blood glucose monitoring device called the iBGStar (Figure 4). This monitor connects directly to any



Figure 4. iBGStar blood glucose monitoring device.

Apple iOS device such as an iPhone, iPod Touch, or iPad. Results of blood glucose readings are immediate and displayed using an iBGStar diabetes manager app. Also, the iBGStar device can be used independently of the iOS device, and glucose values can be synchronized to any iOS device at a later time.¹⁹

To ensure accurate glucose readings, iBGStar uses dynamic electrochemistry. This technology is created by a complex mathematical method that automatically adjusts for factors that can lead to inaccuracies in blood glucose readings such as temperature, humidity, and hematocrit levels.¹⁹ Studies have shown the device to be 99.5% accurate and to meet the International Organization for Standardization's standards for glucose monitors (ISO 15197).²⁰

The iBGStar app was created from the WaveSense Diabetes app described in the section above. The features of the WaveSense Diabetes app are nearly identical to the iBGStar app. Subtle differences in the iBGStar app include improved interface resolution, which is crisp, clear, and visually appealing, and the omission of the video feature of the WaveSense Diabetes Manager app, which contains information on various topics related to living with diabetes.

Traditional SMBG using lancets can be painful and time-consuming; however, promising new technology may one day provide a solution to this problem. High-tech devices such as EyeSense (Grobostheim), which is now in development, may offer alternative procedures for patients to measure their glucose levels without using a lancet. This external meter will be able to determine a blood glucose reading via a small photometer implanted in the interstitial fluid below the conjunctiva of the eye. In studies, this method has been shown to perform as well as conventional

blood glucose meters. It is anticipated to become available in 2013.²¹

Summary and Conclusions

With the advancement of technology, methods for monitoring glucose and other metabolic parameters have become more simple and convenient. As advanced technology continues to become more ingrained into everyday life, it is important for HCPs to have a firm understanding of these new tools.

The apps reviewed in this article demonstrate tremendous versatility, usability, and functionality at nominal or no cost. Some less expensive apps may not meet the needs of all users; however, some patients may find the extra features of more expensive apps to be overwhelming. Apps such as Diabetes Log, which is free in the Apple iTunes store, provide the main essentials for diabetes monitoring, whereas Diabetes Buddy, which costs \$6.99, is a more comprehensive app that offers additional features for more detail-oriented users. Selecting the most appropriate app for a given patient will require consideration of the need for lifestyle modifications such as diet and exercise as well as the user's knowledge of and experience in using smartphones.

These apps also provide alternative avenues in chronic management of multiple disease states in addition to diabetes. Features that store blood pressure and cholesterol data and weight management tools are included in some apps.

As new apps continue to emerge and become more refined, smartphone users will have more options to conveniently track their glycemic control and overall health, which can ultimately improve their ability to effectively manage their diabetes.

In addition, new and emerging devices such as iBGStar and Eyesense may offer still more convenience for users to track their glucose levels while on the move, making the process of SMBG simpler than ever before.

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