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Evolution of Data Management Tools for Managing Self-Monitoring of Blood Glucose Results: A Survey of iPhone Applications

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Abstract

Background:
Studies have indicated that sharing of self-monitoring of blood glucose (SMBG) data and subsequent feedback from the health care provider (HCP) can help achieve glycemic goals such as a reduction in glycated hemoglobin. Electronic SMBG data management and sharing tools for the PC and smartphones may help in reducing the effort to manage SMBG data.

Methods:
We reviewed software and top-ranking applications (Apps) for the iPhone platform to document the variety of useful features. Additionally, in an attempt to assess metrics such as task analysis and user friendliness of diabetes Apps, we observed and surveyed patients with diabetes as they recorded and relayed sample SMBG results to their hypothetical HCP using three Apps.

Results:
Observation and survey demonstrated that the WaveSense Diabetes Manager allowed the participants to complete preselected SMBG data entry and relay tasks faster than other Apps. The survey revealed patient behavior patterns that would be useful in future App development.

Conclusion:
Being able to record, analyze, seamlessly share, and obtain feedback on the SMBG data using an iPhone/iTouch App might potentially benefit patients. Trends in SMBG data management and the possibility of having interoperability of blood glucose monitors and smartphones may open up new avenues of diabetes management for the technologically savvy patient.

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Abbreviations: (ANOVA) analysis of variance, (Apps) applications, (BGM) blood glucose monitor, (BSDC) Blood Sugar Diabetes Control, (DDL) Diamedic Diabetes Logbook, (DM) diabetes mellitus, (HbA1c) glycated hemoglobin, (HCP) health care provider, (PDA) portable digital assistant, (SMBG) self-monitoring of blood glucose, (T1DM) type 1 diabetes mellitus, (T2DM) type 2 diabetes mellitus, (WDM) WaveSense Diabetes Manager

Keywords: blood glucose monitor, data management, iPhone, self-monitoring of blood glucose

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Introduction

Diabetes mellitus (DM) is a public health concern since it affects approximately 17.5 million in the United States[1] and approximately 250 million worldwide.[2] The American Diabetes Association estimates the total annual economic burden of diabetes to be $174 billion.[2] Regular self-monitoring of blood glucose (SMBG) has been advocated as one of the seven vigilant self-care behaviors to achieve integrated management of DM[3] and has shown utility in type 1 diabetes mellitus (T1DM) patients.[4] A meta-analysis[5] concluded that SMBG was associated with significantly improved glycemic control in type 2 diabetes mellitus patients (T2DM). Therefore, placing emphasis on SMBG data makes it imperative to examine the role of data-management tools and their evolution since the 1990s, especially following the landmark Diabetes Control and Complications Trial in 1993.[6] Data-management tools aid in logging SMBG data so that health care providers (HCPs) can recommend interventions regarding diet, exercise, or medication. The ultimate goal of data management is to be able to manage diabetes effectively, to reduce or control glycated hemoglobin (HbA1c), and to prevent or delay the complications of DM.

Azar and Gabbay[7] observed that SMBG data shared by patients with the HCP using Web-based tools saved time and reduced long-term cost. Additionally, unlike T1DM patients, T2DM patients improved their HbA1c significantly. Patients logged or uploaded their results, and HCPs responded via the Internet,[8] text message,[9] or by phone.[10] Researchers in the Ezetimibe and Simvastatin in Hypercholesterolemia Enhances Atherosclerosis Regression trial evaluated portable digital assistant (PDA)-aided SMBG and found it to be useful and promising.[11] Forjouh and colleagues[12] found that, although challenging,[13] PDA-assisted care led to a significant reduction in HbA1c. A meta-analysis[14] found that sharing SMBG data (using logbooks, fax, and Internet) and subsequent feedback (by telephone, video, or in-person appointment) improved glycemic control and reduced the number of hospitalizations. Additionally, adoption of technology depends on the learning curve for the gadget or software and its technical and architectural design.[7] For example, diabetes patients with vision problems might find it difficult to navigate the mini-keyboard interface on smartphones. Nevertheless, the push for smartphone-based solutions gains importance from a demographic standpoint. Today, the cohort with the most smartphone users is aged between 25 and 44.[15] The Centers for Disease Control and Prevention's fact sheet indicates that the cohort that typically has the highest proportion (50%) of newly diagnosed diabetes is between the ages of 40 and 59.[16,17] Assuming that smartphone-user and diabetes-risk demographics do not change, this observation suggests a likely scenario that the smartphone users of today are going to among the diabetes population of the 2010s.

Over the years, data management options have evolved from a simple logbook to a feature-rich Blackberry or iPhone (**Table 1**). A logbook is commonly used for recording SMBG data. Although simple to understand, logbooks require significant commitment to maintain and are prone to documentation errors and inclusion of phantom data.[18] Often, patients do not record the time or the intake of medications, which makes deciphering safety concerns such as hypoglycemic events or glucose patterns difficult to interpret. Blood glucose monitors (BGMs) can store 200–400 test results and can display mean glucose values over a suitable fixed duration (e.g., week or month). However, it is difficult to visualize the SMBG trends because of limitations of software or the size and quality of display. Blood glucose monitor manufacturers usually bundle their monitors with software to allow data to be transferred to a PC or uploaded to a Web server or emailed to HCPs (**Table 2**). Several BGMs offer connectivity to phones. The GlucoPhone (HealthPia, Paducah, KY) is a BGM attached to a VX-5200 cell phone (LG, Seoul, South Korea). GlucoTel (BodyTel Scientific, Nordhessen, Germany) is a BGM that can transfer data via Bluetooth® to a server via short messaging service. Similarly HealthPal (MedApps Inc., Scottsdale, AZ) provides a hub or cradle that accepts BGMs. The cradle communicates with a phone via Bluetooth. Applications (Apps) such as Glucose Tracker (SoundTells LLC) and Health Tracker (Infodevtech, Chennai, India) are available for the Blackberry (Research in Motion, Ontario, Canada). Health Tracker is also available for Nokia phones. However, these Apps are known to work on specific cell phone models.

The iPhone and iTouch (Apple Inc., Cupertino, CA) provide a touch-interfaced, wireless mobile device platform with enhanced multimedia options that is ideal for a diabetes patient who is comfortable with emerging technology. Reflecting a commitment to patient care, Lifescan (Milpitas, CA) developed and demonstrated their App,[19] and Roche Diagnostics (Indianapolis, IN) began a collaboration with MYLEstone Health (Long Island, NY).[20] However, to date, WaveSense Diabetes Manager (WDM; AgaMatrix, Salem, NH) is the only App by a BGM manufacturer that has been released for use on the App store.

Table 1.
Available Methods of Data Management, Their Features, and Proven Benefit

	Portable	Graphing and analysis	Rapid, secure transfer of data	Benefit
Logbook	Yes	No	No	↓HbA1c[14]
Web-based tools	No	Yes	Possible	↓HbA1c, ↓ hospitalization, cost[7]
Smart-phones/ PDA	Yes	Yes	Possible	↓HbA1c[12]
iPhone	Yes	Yes	Possible	Not described yet

Methods

The objective of this manuscript was to review SMBG data management options to record, analyze, and relay data to a HCP and focus on creative features of available iPhone Apps. Applications were selected by

1. Visiting iTunes App Store and searching the healthcare/fitness category,
2. Typing in "diabetes,"
3. Analyzing the "customer ratings" and "customer reviews" information for each App, and
4. Selecting 12 relevant Apps with highest customer rating (as of October 8, 2009).

Applications were evaluated for metrics such as glucose/carbohydrate/insulin input and event tracking (hypoglycemia/hyperglycemia). Following this preliminary analysis (**Table 3**), we chose the three top-rated Apps, namely, Diamedic Diabetes Logbook (DDL), Blood Sugar Diabetes Control (BSDC), and WDM for further review.

Table 2.
Summary of Available Self-Monitoring of Blood Glucose Data-Management Tools [a]

Product Name	Category	Meter	Connectivity to Wireless Phone	Connectivity to PC	Connectivity to Web Services	Company
Accu-Chek Smart Pix device reader	Software	Accu-Chek	No	Wireless-Infrared	-	Roche, Indianapolis, IN
Accu-Chek 360 Diabetes Management System	Software	Accu-Chek	No	USB Cable	None	Roche, Indianapolis, IN
Confidant 2.6	Software	Confidant International	Yes (wireless)	Yes	-	Confidant International, Raleigh, NC
CoPilot Health Management System	Software	FreeStyle Lite, Precision Xtra	No	Serial, USB	No	Abbott Diabetes Care, Alameda, CA
Diabass	Software	Several leading meters	No	Yes	No	mediaspects GmbH, Germany
eSAN/ThinkPositive Diabetes management System	Software/ Hub	OneTouch Ultra 2	Meter with serial connection to cradle, cradle to phone (via BT1.2) to server	No	Yes	t+ Medical, Chapel Hill, NC

Table 2 (cont.).
Summary of Available Self-Monitoring of Blood Glucose Data-Management Tools [a]

Product Name	Category	Meter	Connectivity to Wireless Phone	Connectivity to PC	Connectivity to Web Services	Company
Glucofacts Deluxe Diabetes	Software	Ascensia Contour, Breeze	No	Yes	No	Bayer Healthcare, Tarrytown, New York
Glucofacts Express Data Management Software	Software	Meters from Bayer	No	Serial, USB	No	Bayer Healthcare, Tarrytown, New York
Glucomon	Hub	Supports One Touch Ultra	Yes, wireless	No	GPRS, 2.5 G	Healthcordia, Dallas, TX
GlucoPhone/ GlucoPak/Gluco+	Meter	Glucophone	Yes	No	Planned, MyGlucoSite	HealthPia, Paducah, KY
GlucoseTracker for Symbian OS	Software	Manual entry, any meter	Nokia/ Blackberry	Manual	No	InfoDev Technologies, Chennai, India
GlucoTel	Meter	GlucoTel	Bluetooth	No	Yes via SMS/ GPRS	BodyTel Scientific, Nordhessen, Germany
HealthPAL - MedApps Wellness System	Software/ Hub	Supports One Touch Ultra and Ultra 2	Yes via hub/cradle, wireless	Cradle/USB	Yes, HealthCOM	MedApps Inc., Scottsdale, AZ
Jazz Wireless	Meter	Jazz Wireless	No	Bluetooth	No	AgaMatrix Inc., Salem, NH
MetrikLink	Hub	Several leading meters	No	Yes	MediCompass Connect	Imetrikus, Sunnyvale, CA
Mobile Diabetic	Software	Manual entry, any meter	Nokia/ Blackberry/ Sony	No	No	Mobile Diabetic, Inc., Snohomish, WA
MyGlucoHealth Meter (MGH-BT1)	Meter	MGH-BT1	Yes, Bluetooth	Bluetooth/ USB	Yes, MyGlucoHealth Physicians' Portal	Entra Health Systems, San Diego, CA
One Touch Diabetes Management System	Software	OneTouch Ultra 2	No	Serial, USB	None	Lifescan, Milpitas, CA
Polymap GMA, Symcare software	Software	Any meter	Yes via hub/cradle, wireless	No	Yes, SymCare Diabetes Management Program	SymCare Personalized Health Solutions, Inc., West Chester, PA
The Hermes	Software	Meter with wireless capability	Yes	No	Yes	Palaistra Systems Inc., Buffalo, MN
TrackRecord Data Management Software	Software	TruTrack	No	USB	No	Home Diagnostics, Fort Lauderdale, FL
Zero-Click™ Blood Glucose Data Management System	Software	Wavesense Keynote, Presto	No	USB	No	AgaMatrix Inc., Salem, NH

[a] SMS, short message service; GPRS, general packet radio service.

Table 3.
Features of the iPhone Applications Used for Self-Monitoring of Blood Glucose Data Management

App Feature	Diabetes Log	Glucose Buddy—Diabetes Helper 2.0	WDM, AgaMatrix Inc.	Glucose Charter	DDL (Nicholas Martin)	myBG Lite	BSDC, GP Imports	Islet—Diabetes Assistant	Diabetes Pilot	Track3—Diabetes Planner and Carb Counter	BloodWise	Diabetes Diary
Glucose tracking	x	x	x	x	x	x	x	x	x	x	x	x
Carbohydrate tracking	x	x	x	x	x		x	x	x	x		
Insulin/medicine tracking	x	x	x	x	x		x	x	x			x
Activity tracking		x	x		x		x	x	x	x		
Weight tracking				x	x				x			
Blood pressure tracking									x			
Meal-time tagging	x	x	x		x		x		x	x		
Preset notes			x						x			
Custom notes	x	x	x		x		x	x	x		x	x
Food database				x					x	x		
Color coded for hypo/hyper		x	x								x	
Trend chart length		10d	90d	14d	365d			365d	30d		7d	
Widescreen mode			x					x	x			
Logbook view			x					x		x	x	
Direct entry from logbook			x									
Averages		x	x		x				x	x	x	x
Standard deviation			x		x							
Email composer	x	x	x	x	x	x	x	x	x		x	
Target range settings			x						x			
Background themes			x									
Email (comma-separated values)	x		x		x						x	
Autosynch to Website		x	x			x		x				

Twenty-three individuals consented and participated in the task analysis and survey of aforementioned preinstalled iPod Touch Apps at Atlanta Diabetes Associates, Atlanta, GA. Applications were tested in the order of DDL, WDM, and BSDC. A sole outlier was excluded from the analysis for taking four times the average duration for completing tasks using BSDC. Participants were diagnosed with either T1DM (11) or T2DM (11), were aged between 18 and 66 years (average of 43.7), and were of either gender (12 Male, 10 female). While some participants had prior experience using iPod Touch or iPhone (9), others did not (13).

Participants unfamiliar with this interface used the preinstalled calculator or notepad feature to become comfortable with the basic operation of the iPhone. None of the participants were allowed to navigate the diabetes Apps prior to performing the tasks. After participants familiarized themselves, written and verbal instructions were provided for performing the following tasks:

Task 1

- Enter a blood glucose reading of 80 mg/dl on October 17, 2009, at 5:30 AM. Depending on which App you are using, record the reading with a period of "before breakfast," a meal tag of "prebreakfast," or a category "before breakfast."
- Enter a blood glucose reading of 122 mg/dl on October 17, 2009, at 9:00 AM. Depending on which App you are using, record the reading with a period of "after breakfast," a meal tag of "postbreakfast," or a category "after breakfast."
- Enter a blood glucose reading of 153 mg/dl on October 18, 2009, at 12:30 PM. Depending on which App you are using, record the reading with a period of "before lunch," a meal tag of "prelunch," or a category "before lunch."
- Enter a blood glucose reading of 205 mg/dl on October 8, 2009, at 7:00 PM. Depending on which App you are using, record the reading with a period of "after dinner," a meal tag of "postdinner," or a category "after dinner."
- Enter a blood glucose reading of 75 mg/dl on October 19, 2009, at 8:30 AM. Depending on which App you are using, record the reading with a period of "after breakfast," a meal tag of "postbreakfast," or a category "after breakfast."

Task 2

Add the following note to the lowest result: "Skipped a meal."

Task 3

View the data in a chart (trend chart or graph) and show the technician the highest and lowest readings.

Task 4

Create an email to send past seven day's data to a specific email address (hypothetical HCP).

Each participant was observed and timed by a trained technician. Time taken per task and number of requests for help were recorded. Following this, the written survey was administered with the goal of evaluating the following:

1. Importance and desirability of App features such as number of data reports, appearance, price, ability to communicate with meter (to access data), wireless features, and synchronizing with online databases.
2. Observed ease of use from time taken to complete tasks and participants' requests for help.
3. Perceived ease of use for performing the tasks by scoring the following on a scale of 1 (disagree) to 10 (agree):

   A. It was easy to enter a glucose reading into the App.

   B. It was easy to adjust the date and time of the reading.

   C. It was easy to add a meal-time tag to the reading.

   D. It was easy to add a note to the reading.

   E. It was easy to identify the highest and lowest readings from the charts/graphs.

   F. The email function was easy to use.

   G. It was easy to learn how to use this App.

   H. This App would be useful in diabetes management.

Results

The preselected tasks represent standard steps that patients undergo while recording and relaying SMBG results. Participants completed all four tasks faster with WDM than the other Apps [**Figure 1A**, $n = 22$, one-way analysis of variance (ANOVA) test, $F = 3.23$, $F_{crit} = 3.14$, $p < .05$]. However, for individual task 1 alone, the difference was not significant (one-way ANOVA test, $F = 1.72$, $F_{crit} = 3.14$). The WDM App was also subjectively scored as the easiest to use (8.79) when compared with DDL (7.69) and BSDC (7.84) (**Figure 1B**, $n = 22$, one-way ANOVA, $F = 16.34$, $F_{crit} = 3.012$, $p < .05$). With the WDM, gender of the user, prior exposure to products from Apple Inc., and educational status (college degree or a lack thereof) did not impart any significant difference to the time taken to complete all the tasks. Participants in the younger half (aged 18–44 years) completed all the tasks faster using the WDM (6.3 min) as opposed

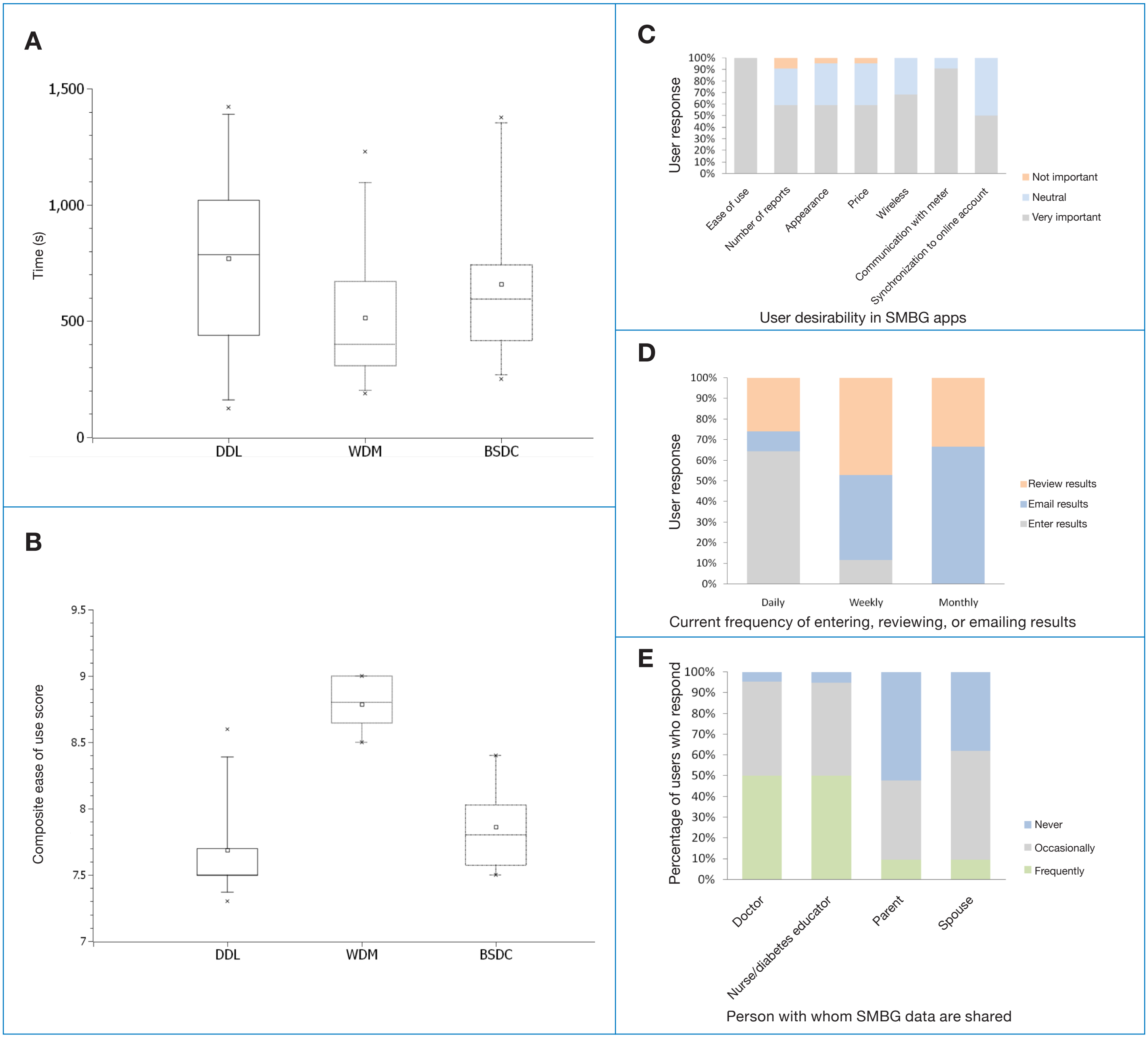

Figure 1. (**A**) Average time (seconds) taken to complete tasks 1–4 with each App (n = 22). (**B**) Composite ease of use score across eight parameters for each App (higher the score, easier the App is to use, n = 22). (**C**) User preference for hypothetical SMBG App features (n = 22). (**D**) User response on current frequency of SMBG activity such as entering, reviewing, or emailing results (n = 22). (**E**) Current SMBG data sharing behavior of participants (n = 22).

to the older half (aged 44–66 years, 10.7 min, $p < .017$). This was true for DDL (9.7 versus 15.9 min, $p < .009$) and BSDC (7.75 versus 14.1 min $p < .002$) as well. On average, the requests for help to complete all tasks were the least with WDM (1.6) as opposed to DDL (5.7) or BSDC (3.4). Desirability of App features (**Figure 1C**); user behavior such as current frequency of SMBG recording, reviewing, emailing pattern (**Figure 1D**); and data-sharing behavior (**Figure 1E**) were noted for future App development.

Discussion

Being able to record, analyze, seamlessly share, and provide feedback on the SMBG data using an iPhone/iTouch might potentially benefit patients. Currently, patients have to enter data manually into the Apps because there is no BGM device yet that directly connects to the iPhone. Solving this challenge may help in saving time and reducing errors in recording data. Our results indicate that the younger participants were able to complete

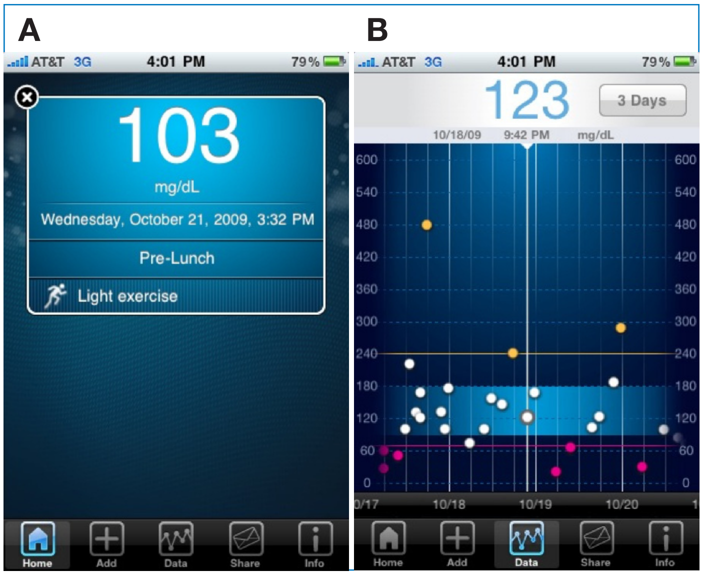

Figure 2. **(A)** WaveSense Diabetes Manager App interface with annotation of "light exercise" to qualify the test result. **(B)** Hypoglycemic/hyperglycemic event tracking using the WDM App.

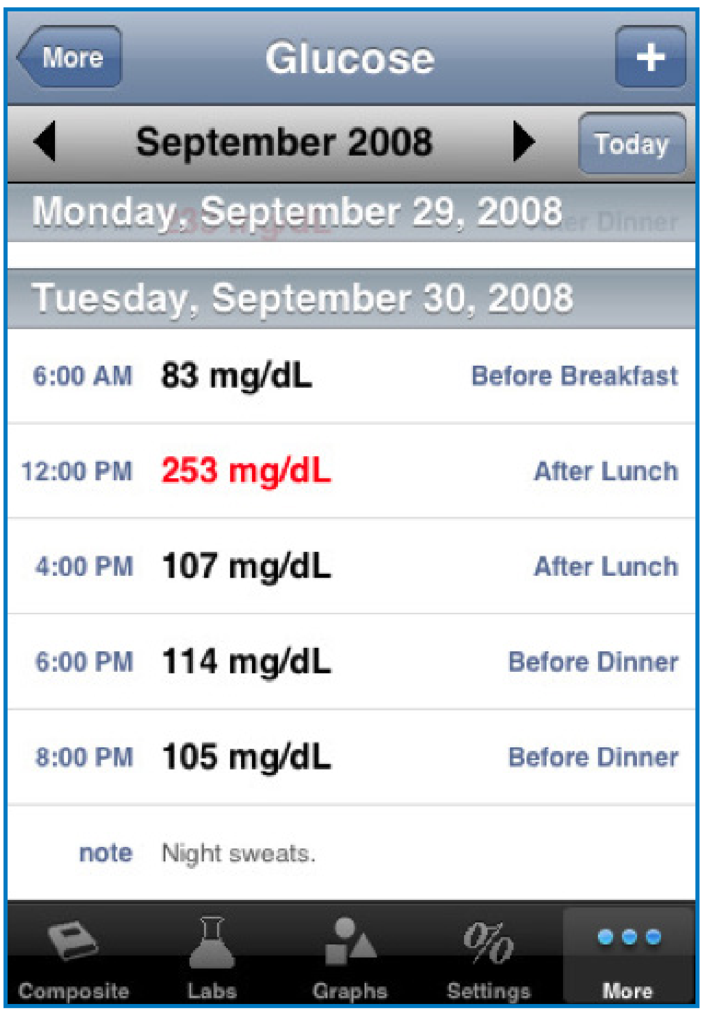

Figure 3. Diamedic Diabetes Logbook App by Nicholas Martin.

tasks faster than the older participants. This is probably because they had prior experience and were more adept at learning or navigating the interface. Therefore, a meter that directly communicates with the iPhone is likely to benefit older diabetes patients.

Our survey has its limitations. It ranked WDM (**Figure 2**) higher than DDL (**Figure 3**) and BSDC, unlike the App store customer ratings, where WDM was third. One reason for this discrepancy might be the subjective perceptions of a limited number of users in our survey. Alternatively, unlike our survey, the App store customer rating lacks granularity and keeps changing over time. Additionally, although there is statistically significant difference between the Apps in the task analysis and the user survey, it remains to be seen if this difference truly imparts any eventual benefit to the user.

Further, clinical studies demonstrating HBA1C reductions typically consist of committed patients, a diligent HCP, and a mechanism to provide feedback. Our survey analyzed standalone Apps and did not explore the role of postprocessing of data or patient feedback by HCP. While patients might find it useful, objective benefit from the Apps to enable intervention and achieve glycemic benefit is yet to be determined.

Conclusion

Achieving glycemic control is challenging, and recording and relaying SMBG accurately is an important intervening step. The transition from logbooks to electronic data-management tools has provided an opportunity to ease this burden by optimizing data collection. Additionally, the convergence and interoperability of BGMs and smartphones has enabled a new paradigm in diabetes management. Adoption of the iPhone as a diabetes data-management tool may hold promise, and keeping abreast of trends, including user behavior and perceptions, helps developers and medical device companies design better tools for disease management.

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