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A Review of Popular Glucose Tracking Apps and Use of mHealth by Latinos with Diabetes

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Committee Chair

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By

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Doctor of Medicine

University of Kentucky

2008

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Abstract

A Review of Popular Glucose Tracking Apps and Use of mHealth by Latinos with Diabetes

By John Williams, M.D.

Background: Diabetes in the United States is a pervasive chronic disease, contributing to hundreds of thousands of deaths each year. Latinos in particular suffer from higher rates of complications and diabetes-related mortality than non-Hispanic Whites. mHealth, defined by the WHO as "medical and public health practice supported by mobile devices," is a promising new treatment modality for diabetes, though few smartphone apps have been designed specifically for Latinos.
Objectives: (1) To identify common features of popular glucose tracking apps; (2) To determine the use of these apps among a sample of online Hispanics in the U.S.
Methods: First, twenty popular diabetes apps were reviewed to ascertain the most prevalent features and functionalities. Second, an online survey in Spanish was developed and fielded through a popular health website for Latinos inquiring about respondents' diabetes status and use of diabetes apps.
Results:
App review: Approximately one-third of apps were available in Spanish. The most common features were blood glucose recording/analysis and activity logs. Most apps permitted exportation of data via e-mail but only a third enabled uploading to an online account. Twenty percent of apps identified could connect directly with a glucometer, and 30% had reminder functionalities prompting patients to take medications or check blood glucose levels. None of the apps reviewed contained dedicated education modules aimed at helping users understand their condition.
Online survey: Over 1,600 surveys were completed. Over 90% of respondents were from the United States, including Puerto Rico. The majority of respondents used a device running on an Android platform while only a quarter used an iPhone. Use of diabetes apps was approximately 3% among diabetics and 3.6% among diabetics who also had a smartphone. Among app users, blood glucose and medication diaries were the most frequently used functionalities while hemoglobin A1c and insulin diaries were the least used. The majority of app users did not share their progress on social media though many of these were willing to share it with their doctor.
Conclusions: Use of diabetes apps among sample respondents was on par with—or even greater than—the global prevalence of diabetes app use. Latinos, however, face significant obstacles in diabetes management, not the least of which are inadequate self-management skills and a lack of diabetes knowledge. The majority of apps reviewed lacked functionalities such as medication reminders and glucometer connectivities that would facilitate diabetes management; diabetes education was also largely lacking in all of the apps reviewed. In order to maximize the potential benefits of diabetes apps in this population, we recommend developers incorporate diabetes education, reminder functionalities to improve adherence to medication and self-management regimens, glucometer connectivities to reduce data entry burden, and optional Spanish language interfaces to accommodate those with limited English proficiency.

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Chapter I: Introduction

Context of Project

Chronic diseases pose significant challenges in developed countries. Diabetes mellitus, one of the most common chronic diseases, affects over 26 million people and is the seventh leading cause of death in the United States (Centers for Disease Control and Prevention (CDC), 2011). It is also a very expensive condition to treat, costing nearly a quarter of a trillion dollars in 2012 (American Diabetes Association (ADA), 2013). The prevalence of diabetes in Latinos is nearly 70% greater than in the general population (Quinn et al., 2008). This population has also been shown to have worse glycemic control (Kirk et al., 2008) and to be 50% more likely to die from diabetes than non-Hispanic Whites (NHWs) in the United States (United States Department of Health and Human Services, 2014). mHealth, an emerging field defined by the WHO as "medical and public health practice supported by mobile devices" (World Health Organization, 2011) has the potential to make a significantly positive impact on the management of chronic diseases worldwide, including within the Latino population. Since the release of the first smartphone in 2007, apps have become a central focus of mHealth innovations, and the number of health and wellness apps has since grown into the hundreds (Ahn, 2014). There is a lack of scholarly research, however, into the benefits of these apps, particularly within the Latino population.

Problem Statement

Research has not kept up with the rate of expansion of the diabetes app market, which is estimated to be growing at a rate of approximately 40% per year (Brandell & Ford, 2013) and the majority of apps currently available have little to no research into outcomes associated with their

use. The meager amount of academic research that exists has focused on the study of apps implemented in tandem with additional interventions such as direct or indirect healthcare provider support, thus confounding attempts to draw direct links between the use of diabetes apps and improvements in diabetes outcomes. The literature surrounding the use of diabetes apps in minority populations is even sparser despite evidence showing that Latinos are just as likely as Whites to own a smartphone (Pew Research Center, 2013a).

Purpose of Project

The overall objectives of this project were to (a) gain a better understanding of the apps targeting diabetics—particularly Latino diabetics—by identifying the features and functionalities most common to today's diabetes smartphone apps and examining their utility in light of the diabetes self-management challenges faced by Latino diabetics as found in previous research, and (b) characterize app usage and preferences for particular app functionalities among Latinos as suggested by our survey of visitors to a Spanish language health website. These insights can be used both to direct Latinos to the currently available apps that may be most suited to their needs and assist researchers and app developers in creating apps uniquely tailored to the needs of a population that may have a high proportion of individuals at risk for diabetes and its complications.

Chapter II: Literature Review

The following literature review will provide an evidence base for mHealth interventions in the treatment of chronic diseases with a focus on diabetes. The review will begin with a discussion of Text4Baby, one of the most successful and widespread mHealth interventions to date. The review will then discuss the evidence for basic mHealth interventions for several chronic diseases. Diabetes will be the focus of the remainder of the review, with specific

emphasis on smartphone apps. Finally, the opportunity for mHealth interventions in the Latino population will be discussed, in particular as they pertain to diabetes apps.

Evidence for mHealth in the pre-smartphone era

Text4Baby is one of the most well-known examples of exploiting mobile technology to improve healthcare outcomes. Created in 2010 and led by the Healthy Mother Healthy Babies Coalition with support from public and private partners such as Johnson & Johnson and the United States Department of Health and Human Services, the program has reached more than 685,000 mothers in just a few short years (Text4baby.com, 2015). The program involves a series of text messages sent to expectant mothers designed to inform, educate, and counsel them during their pregnancy and post-partum periods. More than 250 different messages have been developed by an expert panel addressing topics such as prenatal care, vaccinations, and family violence (2015). Multiple studies have shown a positive change in attitudes towards motherhood (Evans et al., 2014; Evans et al., 2015), though there are few randomized controlled trials (RCTs) to support the program. One RCT conducted by Grabosch, Gavard, and Mostello (2014), however, found that 73% of women who participated in the Text4baby program had baseline blood glucose levels within goal range versus only 20% of those who declined to participate in the program ($p<0.01$).

mHealth and hypertension. Hypertension is a chronic disease that frequently accompanies diabetes in patients and requires them to monitor their blood pressure and take medications daily in order to treat their condition. Tools that help patients carry out these tasks consistently improve blood pressure control and reduce the risk of potentially disabling or fatal adverse events such as strokes or heart attacks. A 2012 study by Logan and colleagues showed that employing mobile devices could improve blood pressure control. The study was a

prospective, randomized, open, blinded primary end-point trial of 110 diabetics with uncontrolled systolic hypertension (systolic blood pressure ≥130 mm Hg on ambulatory blood pressure monitoring) randomized to either a treatment group or a group receiving usual care. The treatment group was provided with a Bluetooth-enabled blood pressure monitoring device that uploaded data to smartphones which then transmitted them to servers. These would then analyze the information using pre-determined algorithms and provide feedback to patients and their healthcare providers. The study lasted a year and the authors found that patients in the treatment group lowered their systolic blood pressures by an average of 9.1 ±15.6 mm Hg ($p<0.0001$) and were 20% more likely to achieve the recommended target of BP <130/80 than patients who received usual care (51% versus 31%; $p<0.05$).

Another study of an mHealth intervention for hypertension by Kiselev and colleagues (2012) conducted in 2008-2009 included 199 Russian subjects diagnosed with hypertension. The intervention involved a treatment protocol consisting of mobile collection and transmission of patient data to healthcare providers, SMS (Short Message Service) reminders regarding hypertension monitoring and self-management, and mobile scheduling of office visits. Telephone consultations with healthcare providers were arranged as needed. Subjects in the control arm of the study had visits with their healthcare provider as frequently as indicated by the severity of their disease. At the end of one year, the patients in the treatment arm were more likely to have blood pressures at goal (BP <135/85) than those in the control arm (HR 5.44, CI 3.2-9.9; $p=0.005$).

mHealth and cardiovascular disease. Cardiovascular disease (CVD) is a broad term encompassing several conditions affecting the heart and blood vessels. One of the most well-known is coronary artery disease, a condition that leads to heart attacks (myocardial infarction).

Like diabetes and hypertension, management of CVD entails routine self-monitoring of measurements such as weight, blood pressure, heart rate, and levels of anticoagulation. mHealth interventions have also been found to be useful in this disease. In a 2012 randomized controlled trial involving 203 survivors of acute coronary syndrome (ACS, a.k.a. heart attack) (Blasco, 2012), treatment group participants transmitted data regarding weight, heart rate, blood pressure, cholesterol, and blood glucose to cardiologists using mobile phones. The physicians then replied to their patients with appropriate recommendations using SMS. Compared with the control group, the treatment group was more likely to achieve blood pressure goals (62.1% vs. 42.9%, p=0.012) and hemoglobin A1c goals (86.4% vs. 54.2%, p=0.018). Another randomized trial by Quilici and colleagues (2013) studied the role of SMS in adherence to daily aspirin therapy following the placement of a cardiac stent. Aspirin use is vital to maintain the patency of a newly placed stent in the arteries of the heart, as it prevents platelets from aggregating and blocking blood flow through the device. Poor adherence to daily aspirin therapy after the placement of a cardiac stent increases the risk of having a second heart attack. In the Quilici study, a total of 521 patients were randomized to either usual care or an intervention consisting of daily SMS reminders to take aspirin. After one month, laboratory testing of blood samples to determine adherence to aspirin therapy showed that non-adherence was more common in the control group than in the treatment group (OR 0.43, 95% CI 0.22-0.86; p=0.01).

mHealth and diabetes. Similar to hypertension and CVD, diabetes requires regular self-monitoring and adherence to medication regimens. In the absence of these, blood glucose values can spiral out of control and lead to complications as kidney disease, neuropathy, and even potentially fatal complications such as heart attack and stroke. Self-monitoring in diabetes is largely more cumbersome than it is for other conditions, as it often necessitates multiple

measurements per day of blood glucose, a task which is painful and expensive. Virtually all aspects of diabetes self-management, however, are amenable to mHealth interventions. Insulin dosing calculations, medication adherence, activity and dietary monitoring, education: all of these can be facilitated through the use of mHealth technology.

Studies have shown that even basic mobile technology can improve diabetes control. Krishna and colleagues (2008) performed a systematic review of mHealth interventions in the pre-smartphone era that summarized the evidence. Their Medline search yielded a total of 20 articles representing 18 studies addressing diabetes and obesity. Of the 20 studies, ten measured changes in hemoglobin A1c (HgbA1c), a measurement that reflects the degree to which a patient's diabetes is controlled; the goal for HgbA1c is <7.0-7.5%. Of these ten studies, nine found a statistically significant reduction in HgbA1c. Six of the ten studies were randomized controlled trials (RCTs). Unfortunately, most of the treatments employed in the studies included combination of interventions so it is impossible to determine which of the components, or combination of components, was responsible for improvements. Most of the studies, for example, incorporated clinician involvement and/or use of personal computers along with basic mobile communications, making causal relationships between blood glucose control and mobile technologies difficult to assess. Nevertheless, the use of mobile technology in these successful studies suggests that mHealth can serve as a valuable component of diabetes management.

mHealth in the Era of the Smartphone

The potential for mHealth reached new heights with the debut of the mass-marketed iPhone in 2007. Unlike the mobile phones that preceded them, smartphones combine the accessibility and convenience of mobile communications with the complexity of computer software, much of it instantly obtainable from nearly anywhere in the country. The world of

possibilities opened up by this technology has provoked intense speculation and fierce debate. PriceWaterhouseCoopers, a global business consulting firm, predicts that widespread use of mHealth products could reduce both administrative burden and cost on the United States Healthcare system through a reduction in emergency room visits and a decreased necessity for face-to-face appointments (2013). Many mHealth technologies, however, qualify as medical devices and are therefore subject to costly evaluation and regulation by the Food and Drug Administration. The debate over the proper oversight of this burgeoning field has even reached the halls of Congress in the forms of legislation and counter-legislation (Slabodkin, 2013 and 2014).

There are a myriad of functionalities available across the hundreds of diabetes apps available for download on Apple and Android platforms. While many of these functionalities can be found on various mobile-enabled diabetes websites, apps possess inherent advantages over websites including the capacity for offline use and access to the innate features and computing power of mobile devices (Summerfield, 2015). There is no universal consensus on what constitutes a "diabetes app," but the vast majority facilitate to some degree the recording and analysis of blood glucose measurements, and to a lesser degree the monitoring of diet, exercise, and medication consumption. Additional features such as glucometer connectivity and links to online forums are more variably present. Smartphone apps for diabetes can increase the quality and quantity of data available for diabetes self-management while reducing the burden of data collection and analysis; enhance and facilitate interaction with healthcare providers; and both increase knowledge and change attitudes surrounding the disease. Data regarding the effect of diabetes apps on long-term outcomes such as disease-related mortality are lacking, however, because this technology has been available for less than a decade. Studies into the effects of

apps on intermediate outcomes—hemoglobin A1c in particular—are far more common, though few of these isolate the effects of diabetes apps from concomitant interventions by healthcare providers. Making this distinction is important because many Latino diabetics do not have a usual source of care and thus the benefits of diabetes apps isolated from healthcare provider interaction are a subject in urgent need of study.

The Mobile Diabetes Intervention Study (Quinn et al., 2011) was a one-year cluster-randomized clinical trial that randomized 26 primary care practices in Maryland to one of four groups. Participants chosen from the practices were type II diabetics between the ages of 18-64, had a previous hemoglobin A1c measurement of ≥7.5%, and had Internet or e-mail access. The control group received usual care while the interventions for the three remaining groups consisted of a mobile diabetes management software application with or without clinician involvement. The software package used by participants enabled them to track blood glucose values, food intake, and medication administration while receiving automated response messages specific to their data. One of the three study groups were given the software component only; the second study group included clinician access to unanalyzed patient data; and the third group included clinician access to patient data as well as quarterly summary reports analyzing patients' metabolic control, medication adherence, and self-management skills with reference to relevant evidence-based guidelines. Results from the study included a 1.9% drop in HgbA1c (95% CI 1.5-2.3) among the third study group in which clinicians had access to analyzed patient data and evidence-based guidelines. More importantly, HgbA1c also declined in the treatment group involving diabetes management software without any clinician involvement ($p=0.02$), suggesting that mobile diabetes management software can improve diabetes control independent of

healthcare provider involvement. This scenario is more befitting of the predicament in which many Latinos find themselves.

A 2013 Japanese study conducted by Waki and colleagues (2014) studied a similar intervention named DialBetics in which type 2 diabetes patients used smartphones to transmit data to servers monitored by healthcare professionals. The study was a 3-month, non-blinded, randomized, controlled study that included 54 able-bodied, smartphone-literate Japanese patients diagnosed with uncomplicated Type II Diabetes. The primary outcome, HgbA1c, was measured at baseline and at three months. The difference in HgbA1c between groups was analyzed using a 1-sided, 1-way analysis of variance t-test on paired readings. Hemoglobin A1c was found to decrease by 0.4% in the study group and increase by 0.1% in the control group ($p=0.015$). Fasting blood sugar was also found to be statistically significantly lower in the study group ($p=0.019$). While the study's findings were encouraging, the outcomes cannot be traced solely to the smartphone program alone. Participants were also required to be smartphone-literate and moderately well-controlled in their disease, further limiting the study's generalizability. Nevertheless, the vast majority of users found the advice they received via the intervention to be helpful (75%) and thought that it helped improve their lifestyle and diabetes self-management (96%). All participants surveyed felt that use of the intervention was worth the time spent.

The TeleDiab 1 study (Charpentier et al., 2011) was a French study that specifically studied poorly controlled type I diabetics. Type I diabetics are a unique group of diabetics who require daily injections of insulin and thus have a more intense self-management regimen. The study was a six-month open-label, parallel group, multicenter study of 180 patients who were randomized to one of three groups. The two treatment groups received smartphones pre-loaded with Diabeo, a software program that enabled users to calculate insulin doses based on several

variables and adjust doses when target blood glucose levels were not achieved. Of the two treatment groups, one received usual follow-up care at the hospital while the other had teleconsultation sessions with a healthcare professional every two weeks over the course of the study. ANCOVA analysis was used to analyze changes in HgbA1c among the three groups. Values were found to increase by 0.2% ± 0.8% in the control group while HgbA1c declined by 0.5% ± 0.9% in the group using the Diabeo software alone and by 0.7% ± 0.8% in the group using the Diabeo software in combination with teleconsultations. The between-group difference in HgbA1c change over the 6-month period was statistically significant when comparing either intervention group with the control group ($p \leq 0.001$). The results were also comparable with those achieved by using a continuous blood glucose monitor (Deiss et al., 2006), a more invasive blood glucose measurement device usually reserved for patients with poorly controlled diabetes. Complementing the previous studies which included only patient with type II diabetes, the TeleDiab 1 Study provides evidence that smartphones are a valid mHealth intervention even for type I diabetics who require more meticulous self-management.

In contrast to the studies discussed above, the 2013 study by Kirwan, Vandelanotte, and colleagues (2013) evaluated the use of a commercially developed app outside an academic research setting. The diabetes app, Glucose Buddy, is a smartphone app available for download on both Apple and Android platforms. The basic version of the app is free while the more comprehensive version of the app requires payment. Regardless of app version, numerous functionalities are available including blood glucose documentation and annotation, medication tracking, and dietary monitoring. To evaluate this app, researchers in Australia recruited 72 type I diabetics between the ages of 18 and 65 who owned a smartphone. Patients allocated to the usual care arm continued their routine diabetes care and follow-up with their healthcare

providers while patients in the treatment arm downloaded a free version of the Glucose Buddy app. Participants in the treatment arm did not receive further instruction on how to use the app or how often to use it, thus approximating a real-life scenario more closely than for academic studies. Data logged into the app were reviewed by a certified diabetes educator and participants in the treatment group received a personalized text-message once a week for the first six months of the study. Hemoglobin A1c data collected at 3, 6, and 9 months were evaluated using linear mixed effects models for repeated measures. The intervention group was found to have a significant decrease in HgbA1c (mean -1.10, SD 0.74; $p<0.001$) over the course of the study compared to the control group which had a statistically insignificant increase (mean 0.07, SD 0.99).

Unlike the studies preceding it, the Kirwan et al. study demonstrates the efficacy of a freely available and popular diabetes app developed outside an academic research setting. This distinction is important because the vast majority of diabetes apps downloaded by users are not developed in academic settings, nor do they undergo the rigors of clinical trials required of entities like pharmaceutical manufacturers. None of the Glucose Buddy developers has any graduate medical education, though their product has been clinically proven to be beneficial in combination with healthcare provider support. While such a pattern of production runs contrary to the usual evidence-based, capital-heavy development of other medical treatments such as pharmaceuticals or invasive medical devices, this novel production paradigm may be largely responsible for the affordability—and thus accessibility and potential benefit—of smartphone technology (particularly for Latinos). Given that commercially developed apps predominate on all app markets, there is a fundamental disconnect between existing research –largely composed of studies of apps developed in academic settings and implemented in tandem with interventions

by skilled healthcare personnel—and the reality of individuals using apps developed by small companies or individuals for self-management and separate from healthcare provider interaction. In short, research has not yet addressed whether diabetes apps developed in the private sector possess the intrinsic capacity to improve diabetes outcomes.

Evidence for mHealth among Latino diabetics

Latinos and Socioeconomic Risk Factors

Diabetes affects over 8% of the United States population (CDC, 2011) but the prevalence is almost 70% greater among Latinos (Quinn et al., 2008). This group has been found to lack in health literacy which in turn increases the risk of poor glycemic control (Schillinger et al., 2002). Latinos have also been found to lack in basic diabetes health behaviors (Nwasuruba et al., 2009) and suffer from a perceived lack of quality health care (Carter, Pugh, & Monterrosa, 1996). Not surprisingly, Latinos have been found to have worse glycemic control than the general diabetic population (Kirk et al., 2008) and are much more likely to die from diabetes than are non-Hispanic Whites in the United States (United States Department of Health and Human Services, 2014). The Latino population in the United States is ethnically and socioeconomically heterogeneous, however, and risk factors for the development of diabetes are present to varying degrees within the population. The distribution of the disease among Latinos has been found to be associated with an interrelated host of factors such as country of origin, time in the United States, household income, and educational attainment. The 2011 Hispanic Community Health Study/Study of over 16,000 individuals of Latino descent (Schneiderman et al., 2014) found that diabetes prevalence decreased with increasing educational attainment ($p=0.0005$) and household income ($p=0.0043$) but increased with length of residence ($p=0.001$). Similar findings to the latter have also been found for the association between diabetes prevalence and immigrant

generation (first-generation immigrants versus second- and third-generation immigrants) even when controlling for lifestyle and socioeconomic factors (Afable-Munsuz, Mayeda, Pèrez-Stable, & Haan, 2013). It has been posited that the process of assimilating to the lifestyle of a typical United States citizen itself increases the risk for developing diabetes independent of the gains associated with United States residence. In particular, the educational and financial gains frequently experienced by the children of immigrants may paradoxically lead to less healthy habits as second-generation Latinos acquire educations permitting advancement to higher paying, more sedentary employment and the adoption of more expensive and calorie-dense diets. Interventions for chronic diseases that take this transition into account may be useful, particularly in 2+ generation immigrants. First generation immigrants may benefit more from interventions focusing on cultural barriers and obstacles to healthcare access. The pervasive use of mobile communications among all Latino demographics (Pew Research Center, 2013) suggests that regardless of generation, mHealth interventions have the potential to be effective.

Latinos and basic mHealth interventions. Research into the efficacy of diabetes apps among Latinos is largely lacking. Very few apps have been designed specifically for this population despite the increased incidence of and complications from diabetes. Limited evidence from other mHealth interventions suggests, however, that this population stands to significantly benefit from diabetes apps. In the Text4Baby study, Spanish-speaking women were found to be more satisfied with the program than English-speaking women (California State University San Marcos Office of Communication, 2011). The TExT-MED program (Arora et al., 2012) was a brief prospective study of a similar intervention that took place in Los Angeles in 2012. A total of 23 patients were recruited from the emergency room of a public safety-net hospital with seventy percent of them being Latino. The intervention included educational and

motivational text messages, medication reminders, healthy living challenges, trivia questions, and numbers linking users with free gifts to help them manage their diabetes. All messages were delivered using the text message functionality common to most mobile phones. Because the study duration was only three weeks, changes in HgbA1c could not be adequately assessed. Using pre-post questionnaires, however, researchers found improvements in self-efficacy (assessed using the Diabetes Empowerment Scale-Short Form, increased from 3.9 to 4.2 pre vs. post), increased medication adherence (as measured by the Morisky Medication Adherence Scale, increased from 3.5 to 4.75) and high levels of satisfaction with the program. Ninety percent of participants said they would like to continue the program and 100% said they would recommend it to family or friends. While brief, of small sample size, and not representative of diabetes control as determined by HgbA1c, the study suggests that mHealth interventions for diabetes would likely be well-accepted by Latinos and may improve diabetes control.

Latinos and mobile technology. Research suggests that Latinos rely more heavily on mobile technology than the general population. A 2014 survey of over 2,000 adults by the Pew Research Center found that over three times as many Latinos rely on smartphones for online access compared with whites (Pew Research Center, 2015). In the *2014 Hispanic Market Overview* by Experian Marketing Services, smartphone ownership was found to be higher among Hispanics (63%) than among non-Hispanics (60%) (2014). Among smartphone owners, Hispanics were also more likely to say that they access the internet through their phone rather than through a computer (45% versus 38%) (Experian, 2014). PricewaterhouseCoopers has reached the similar conclusion that "Hispanic consumers are using their mobile devices to do more things, more often than non-Hispanics (2014). The Hispanic Millenial Project, a joint research study by an advertising agency (Sensis) and a market research firm (ThinkNow

Research), conducted a nationwide online survey in June 2014 with over 900 individuals stratified according to age and Hispanic origin. In their research they found that Hispanics 18-34 years of age (so-called "millennials") were more likely than non-Hispanics of the same age group to use apps for health reasons (ThinkNow Research, 2014). In total, Latinos' access to and usage of mobile health technology suggests that this population stands to significantly benefit from smartphone apps, including those for diabetes.

Smartphone apps for Latinos. A certain amount of technological and health literacy is assumed when producers of health apps design their products. Despite their comparable technological literacy, Latinos have been found to be more health illiterate than the rest of the United States population and are the group with the largest proportion of low health literacy adults (65%) in the United States (Bender, Martinez, & Kennedy, 2015). Low health literacy, in turn, has been shown to lead to poor glycemic control (Schillinger et al., 2002). In a 2007 joint research report by the Pew Hispanic Center and the Robert Wood Johnson Foundation in which over four thousand adult Latinos were interviewed, Latinos were found to be twice as likely as non-Hispanic blacks and three times as likely as non-Hispanic Whites (NHWs) to lack a regular health care provider(Livingston, Minushkin, & Cohn, 2008). The same study found that Latino adults were more likely to receive information about health and healthcare from the media than from medical professionals (83% versus 71%) (Livingston et al., 2008). It stands to reason, then, that highly accessible and relatively cheap diabetes apps ought to help Latinos with limited health knowledge and/or healthcare access understand their disease rather than simply manage it. Diabetes education, however, is under-represented in today's diabetes apps but has been consistently shown to be an integral component of diabetes management and is considered by the American Diabetes Association to be one of the foundations of diabetes care (ADA, 2015). A

2013 overview of systematic reviews confirmed that diabetes education and support are consistently effective methods of improving glycemic control (Worswick et al., 2013). The benefit of such interventions extends into the Latino population as well (Metghalchi, et al., 2008); Rosal, et al., 2011) and is similarly supported by meta-analyses (Ricci-Cabello, et al., 2014; Ferguson, S., Swan, M., & Smaldone, A., 2015). In their 2011 survey of 137 diabetes apps across multiple platforms, however, Chomutare and colleagues found diabetes education modules to be present in only 20% of the apps reviewed (Chomutare, Fernandez-Luque, Arsand, & Hartvigsen, 2011). Latinos currently comprise over 17% of the United States population (United States Census Bureau, 2015) and are projected to make up almost a third of the population by 2050 (Passel & Cohn, 2008). The confluence of this trend and several potential factors—including increased access to health insurance through the Affordable Care Act, coverage of diabetes apps by insurance companies (Jahns, 2014), cost savings generated through mHealth (Jahns, 2014), increased global use of diabetes apps (Jahns, 2014), and government oversight of app content (United States Department of Health and Human Services, Food and Drug Administration, Center for Devices and Radiological Health, & Center for Biologics Evaluation and Research, 2015) necessitate that dedicated efforts to maximize mHealth approaches to diabetes care for Latinos become a national healthcare priority. Our research aims to help bridge the disconnect between the characteristics of the most popular diabetes apps and the needs of the Latino population.

Chapter III: Manuscript

Title Page

A Review of Popular Glucose Tracking Apps and Use of mHealth by Latinos with Diabetes

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Contribution of Student [required for Rollins thesis only; not for publication]

I was involved in this project from the beginning. I personally selected and reviewed all of the glucose tracking apps and had a major part in designing the diabetes questionnaire that was posted on the *HolaDoctor* website. The raw data from the questionnaire were forwarded to me for analysis and interpretation. I wrote and prepared the manuscript for publication, created all figures and tables, and was responsible for interacting with the article's reviewers and the journal's editor.

Introduction

Diabetes mellitus in the United States. Diabetes affects almost 26 million Americans—over 8% of the US population—and is the seventh leading cause of death in the United States (Centers for Disease Control and Prevention, 2011). Among Latinos, the proportion affected is approximately 11.8%, an almost 70% greater prevalence than in the general population (Quinn et al., 2008). According to the American Diabetes Association, the total cost of diabetes-related expenditures in 2012 was almost a quarter of a trillion dollars, translating to an average medical expenditure of almost $14,000 per patient (American Diabetes Association, 2013). A major source of these expenditures is hospitalizations, which have been shown to cost more for patients who have diabetes (Meng et al., 2014). According to 2011 data from California where over a third of the population is Hispanic (United States Census Bureau, 2015), the average cost of a hospitalization for a patient with diabetes exceeded that of a non-diabetic patient by over $2,000 (Meng et al., 2014). Almost a third of all hospitalizations in California that year were for diabetic patients, a proportion which rose to over 40% among Latinos and was higher than that of African- or Asian-Americans (Meng et al., 2014).

Contributing to the problem is a lack of health literacy among Hispanics (Schillinger et al., 2002) which increases the risk of poor glycemic control (Schillinger et al., 2002). Latinos have been shown to lag behind African-Americans and Whites in important health behaviors such as checking blood glucose levels, performing diabetic foot exams, and getting recommended vaccinations (Nwasuruba et al., 2009). These findings are compounded by the feelings of many Latino patients that the care they receive from providers is frequently sub-standard (Carter, Pugh, & Monterrosa, 1996) and problematic (Rodriguez, Chen, & Rodriguez,

2010). The number of Latino healthcare providers relative to the population is also small (Lopez & Grant, 2012), and the resulting language challenges can lead to decreased patient compliance and worse outcomes (Carter et al., 1996). Altogether, Latinos have worse glycemic control than the general diabetic population (Kirk et al., 2008), are 60% more likely to start dialysis, and 50% more likely to die from diabetes than NHWs in the United States (United States Department of Health and Human Services, 2014).

The potential for mHealth. mHealth is a promising new treatment modality for diabetic patients that has been shown in studies to improve glycemic control (Quinn et al., 2008; Charpentier et al., 2011; Kirwan et al., 2013). It has also been found to be a potential source for cost savings and reduced burden on the healthcare system (PricewaterhouseCoopers, 2013). Though mHealth is broadly defined by the World Health Organization as "medical and public health practice supported by mobile devices" (World Health Organization, 2011), the arrival of the smartphone in 2007 has caused an exponential proliferation of smartphone applications which have garnered ever-increasing attention among clinicians, researchers, and the federal government (Slabodkin, 2013; Slabodkin, 2014). To date, there are few apps targeted specifically at Latinos with diabetes. This represents a missed opportunity, as over 90% of Latinos use a cell phone regularly—almost half of which are smartphones (Google, 2010)—and they are just as likely as Whites to own a smartphone (Pew Research Center, 2013). Given the challenges facing Latino diabetics with respect to health literacy and performance of health behaviors in the face of limited access to quality care, increased use of glucose tracking apps could facilitate reductions in poor outcomes in this population.

Technology and the Latino community. Evidence suggests that Latinos already have the capacity to use mobile technology to increase healthy behaviors. The Text4Baby Program, for example, involved the dissemination of text messages to pregnant women and mothers of newborns. A study by the National Latino Research Center revealed improvements in participants' health knowledge, appointment attendance, and immunization adherence. Satisfaction with this program was also found to be higher among Spanish speakers (California State University San Marcos, 2011). The TExT-MED study in Los Angeles involved a similar intervention in which text messages were sent to low-income inner-city patients with diabetes, almost three-fourths of whom were Latino. Results included improvements in healthy eating, increased physical activity, and higher medication adherence (Arora, Peters, Agy, & Menchine, 2012). These studies suggest that simple interventions can be accepted and lead to improvements in healthy behaviors in Latinos, including those with diabetes.

Despite these encouraging findings, there is little research into the use of glucose tracking apps by Latinos or on which app functionalities are the most pertinent to this population. Recommendations endorsing specific apps for Latinos have been put forth by various organizations (American Association of Diabetes Educators, 2015; American Association of Retired Persons, 2012) though these are not research-based. There is therefore an unmet need for scholarly research into how smartphone technology can best benefit Latinos suffering from diabetes.

Goals of the study. The goals of our study were two-fold. First, we sought to identify the most prevalent functionalities of the most popular glucose tracking apps currently available. Second, we aimed to survey the usage of glucose tracking apps among Latinos visiting a popular Spanish-language health website. In light of the challenges facing Latino diabetics, we

attempted to set forth some basic guidelines for apps ideally suited to this population.

Methods

Overview. A systematic search strategy was used to select and review the most popular glucose tracking apps from official smartphone stores. Each app was then examined and functionalities common to multiple apps were compiled into Table 1. A survey inquiring into glucose tracking app usage was then posted on the HolaDoctor website for a total of three weeks, during which time 1,601 surveys were completed.

Review of glucose tracking apps.

Overview. Searches for eligible apps on the iPhone and Android platforms were conducted On January 4th (Apple) and 5th (Android), 2014. A total of ten apps were selected from each platform (five free and five paid). iPhone apps were selected by navigating to the Medical section of Apple's App Store and clicking the link "View Medical in iTunes" in the upper right hand corner. This required previous installation of iTunes on the computer's hard drive (Apple, 2014). Android apps were selected in a similar fashion by locating the list of the top free and paid medical apps on the Google Play website (Google Play, 2014). The first five apps in each section meeting eligibility criteria were selected. Because some apps had versions available on both iPhone and Android platforms or had both free and paid versions listed in the search results, several of the selected apps had multiple versions reviewed. The authors felt this would not be redundant, however, as features of such apps were found to vary depending on platform and cost.

Eligibility Criteria. Apps were considered eligible if they could be found in the "medical" section of the Apple or Google Play stores and had the capacity to record and recall blood glucose measurements. All apps selected for review possessed additional functionalities

(see Appendix), though the quantity and characteristics of these were not considered during the selection process.

Data extraction. Reviews of all iPhone apps with the exception of Track3 by Coheso, Inc. were carried out on an iPod Touch running iOS version 6.1.5. Evaluation of the Track 3 app required a more recent version of iOS, thus an iPhone 4S running iOS version 7.0.4 was used. Reviews of Android apps were carried out with either a Nexus 4 running Android version 4.4.2 or a laptop running BlueStacks App Player for Windows (beta-1). App functionalities for all apps were investigated by author JW. Product descriptions from the Apple App Store, Google Play website, or app developer websites were referenced as needed to clarify uncertainties. Apps were classified as being available in Spanish if either a change in the language setting of the smartphone device from English to Spanish resulted in a meaningful change in the language of the app display or if the app itself had a language setting that included Spanish. Prices listed for each app were current as of January 4 (Apple App Store) or January 5 (Google Play website), 2014.

Online Survey. An online survey was posted on the HolaDoctor website (www.holadoctor.com) from April 15 to May 1, 2014 (see Appendix). HolaDoctor's website, also available through Univision.com as *Univision Salud con HolaDoctor*, is the most frequently visited Spanish language health website on the Internet, with over 3.5 million monthly unique visitors, of which over 1 million reside in the U.S. Over half of HolaDoctor's traffic access the website through mobile devices. The survey was available only in Spanish. Questions explored respondents' diabetes status as well as use of smartphones and glucose tracking apps. A total of 1,161 surveys were completed over an initial 17-day period. After several user comments reported unfamiliarity with the term "app," a second survey using clarifying language was posted

from May 12 to May 19, 2014. This resulted in the completion of an additional 440 surveys for a total of 1,601 surveys. Summary data can be found in Table 1.

Results

Review of glucose tracking apps. The results of the app review can be found in Figure 1 and in the Appendix. A total of twenty apps were reviewed, though some apps were reviewed multiple times as described in the Methods section. It should be noted that while the ability to record and recall blood glucose measurements was the primary selection criterion, analytical capabilities such as calculations of averages and creations of figures including graphs and flow sheets invariably accompanied this functionality. Thirty-five percent of all apps reviewed were available in Spanish (20% of iPhone apps and 50% of Android apps). The ability to annotate blood glucose readings was the most common feature, while passcodes and the capacity for multiple user profiles were the least common. Only 20% of apps could download data directly from glucometers.

Price. The price of apps ranged from free up to ten dollars with the average price of paid apps being approximately $5.03. The average price for iPhone apps ($6.39) was higher than that for Android apps ($3.66).

Documentation functionalities. Activity logs (85%) were the most prevalent documentation functionality followed by insulin logs (80%), weight logs (75%), and carbohydrate logs (70%). While 80% of the apps reviewed included insulin administration logs, only 65% included logs for oral or injectable non-insulin medications. Carbohydrate and food logs (70% and 65%, respectively) were featured more often than calorie logs (30%).

Information sharing. Data export via e-mail was present on 80% of apps while social media connections were featured on 65%. Fewer than a third of apps allowed users to upload

their data to online app-sponsored accounts.

Glucometer connectivity. Twenty percent of apps permitted download of blood glucose measurements from a glucometer. The prevalence of this functionality was equal for both Apple and Android apps.

Online survey.

Diabetes demographics. Table 1 shows the results of the online survey. A total of 1,601 surveys were completed. Approximately two-thirds (n=1,103) of responses came from the continental United States and a quarter (n=353) came from Puerto Rico. Fewer than three percent (n=46) were from Mexico. Fifty-four respondents marked "unknown." More than a third of respondents (n=588) reported a history of diabetes, and 17% (n=276) reported caring for a family member with the disease. Among those who reported a personal history of diabetes, 13% reported having type I, 69% reported having type II, and 18% did not know which type of diabetes they had. Among those reporting type I diabetes (n=74), fewer than half reported taking insulin.

Smartphone usage and diabetes app usage. Almost 80% of respondents (n=1,247) reported using a smartphone. Approximately two thirds (n=815) of these used Android devices while nearly a third (n=415) used an iPhone; seventeen respondents used a Blackberry. Roughly two percent (n=33) of all respondents reported using a glucose tracking app; this increased to 3% among diabetics and 3.6% among respondents with both a history of diabetes and smartphone use. Among diabetics who used apps, about half (n=10) used them in Spanish while about a quarter (n=4) used them in English. Almost a quarter of respondents reported not knowing in which language they used the app.

Cost. Nearly half of diabetic app users downloaded free apps. This proportion increased

to 62% when excluding respondents unable to recall the price of their app. Conversely, over a third of respondents able to recall the price of the app paid money for it. Of these five respondents, three of them paid three dollars or more.

Documentation and reminder functionalities. Tracking of oral medications was the most popular documentation functionality (half of respondents), followed by blood glucose monitoring (44% of respondents). Exercise tracking was featured less often than dietary monitoring of carbohydrates or calories consumed (22% versus 33%, respectively). Insulin and HgbA1c tracking were the least commonly utilized documentation functionalities (17% each). Over three-fourths of respondents reported frequent use of reminders to check blood glucose or take medications.

Information sharing. The majority of respondents (83%) either kept their data private or shared it only with their doctor. The remaining 17% shared information about their diabetes on social media outlets such as Facebook, Twitter, or diabetes forums.

Discussion

Summary of study. In this study, we set out to characterize the most prevalent functionalities for popular glucose tracking apps and survey Latinos on their use of these apps. We went about this task by selecting and reviewing twenty of the most popular glucose tracking apps on the market as of January, 2014 and posting an online survey on one of the most popular Spanish language health websites on the Internet. In our app review we found blood glucose analytical instruments (e.g. graphs, flow sheets, statistics) to be the most prevalent functionalities. These were frequently accompanied by documentation of dietary and biometric data as well as functionalities enabling users to share data on social media. In contrast, a minority of apps were available in Spanish, contained reminder functionalities encouraging adherence to blood glucose monitoring and medication regimens, or allowed download of data

directly from glucometers.

Our online survey found that approximately three percent of respondents with diabetes used a glucose tracking app, a proportion that is higher than the estimated global average of 1.2% (Jahns, 2014). Of these, the number of respondents running their apps on Android products was nearly double the number of those running their apps on Apple products. Most of the apps used were free to download. Fifteen percent of respondents reported not knowing their diabetes status and fewer than half of self-reported type I diabetics reported using insulin. These findings support the findings from other studies (Schillinger et al., 2002; Arora, Marzec, Gates, & Menchine, 2011; Menchine, Marzec, Solomon, & Arora, 2013; Carbone, Rosal, Torres, Goins, & Bermudez, 2007) that there is a lack of diabetes knowledge and awareness among Latinos.

Comparison with the literature. At least three studies have been completed on the prevalence of various glucose tracking app functionalities using systematic search strategies (Chomutare, Fernandez-Luque, Arsand, & Hartvigsen, 2011; Rao, Hou, Golnik, Flaherty, & Vu, 2010; Demidowich, Lu, Tamler, & Bloomgarden, 2012). Two of the studies reviewed apps limited to one platform. The 2011 article by Chomutare and colleagues is the only study of the three to consider both major platforms, reviewing 49 iPhone apps and 33 Android apps. In comparison with this 2011 review, we found a significantly greater prevalence of multiple functionalities including medication management, diet management, physical activity monitoring, and disease-related reminders. The starkest contrast between the earlier review and ours was the prevalence of social media. Only 15% of apps had social media functionalities in the 2011 review versus 65% of apps in our review. This contrast most likely reflects the growing role of social media in daily life (Socially Stacked, 2014).

A limited number of studies have evaluated glucose tracking app use in a specific

segment of the population. An article by Arnhold and colleagues (2014) studied the usability of glucose tracking apps among patients ages 50 years and older. Our study, while not providing empirical evidence as to which app functionalities work best for a specific subgroup, agrees with Arnhold's finding that there is a need for further investigation into how smartphone apps can be tailored to specific target audiences.

How glucose tracking apps designed for Latinos should be different. Latinos lag behind NHWs in levels of health literacy, which in turn has been shown to affect glycemic control (Schillinger et al., 2002). This population also tends to have worse self-management practices (Agency for Healthcare Research and Quality, 2011), including lower levels of physical activity and inconsistent self-monitoring of blood glucose (McGruder, Malarcher, Antoine, Greenlund, & Croft, 2004). Glucose tracking apps should address these disparities in knowledge and practice using carefully selected functionalities tailored to this population.

Education. Education has been shown to be an underrepresented feature of most glucose tracking apps but should be included in apps for Latinos considering both the lower overall levels of educational attainment of Latinos relative to NHWs (United States Census Bureau, 2013) as well as the findings of our survey. Content should be provided at a basic reading level and available in both English and Spanish. In addition, audio or video-based educational materials could complement text, as they may help bypass literacy barriers and would likely be well-accepted among Latinos who are already major consumers of online multimedia (Google, 2010).

Self-management functionalities. Self-management functionalities focusing on blood glucose monitoring, diet, and exercise should be easy to use and motivational. The number of functionalities on a single app should be kept to the minimum necessary to encourage

consistency without decreasing usability (Rao et al., 2010). Self-management practices can be encouraged by minimizing the burden of data entry and by employing reminders (e.g. to check blood glucose or take medication) to minimize unintentional nonadherence (Hugtenberg, Timmers, Elders, Vervloet, & van Dijk, 2013; Fenerty, West, Davis, Kaplan, & Feldman, 2012).

Data Entry Burden. Data entry burden can be reduced through the use of simplified graphic interfaces with adjustable text and icon sizes for elderly or visually impaired users (Usability.gov, 2015) as well as glucometer connectivity. Glucometer connectivity is currently lacking in most popular apps according to our study which found that only 20% of the apps reviewed had this capacity.

Reminders. Reminder functionalities were available in fewer than third of the apps reviewed, though our survey found that over three-fourths of respondents used reminders regularly. Automated reminders can serve several functions, not the least of which could include boosting medication adherence and self-monitoring of blood glucose. Periodic reminders for feet exams, physician visits, and yearly flu vaccines can also be incorporated. Besides conveying instructions, reminders can be educational and/or motivational in a manner similar to the text-message interventions used in the Text4Baby and TExT-MED programs. App content should always be culturally appropriate (Hawthorne, Robles, Cannings-John, & Edwards, 2010) and mindful of social determinants of health as well as the social and cultural heterogeneity within the Latino population itself (Zsembik & Fennell, 2005).

Limitations of the study. Our app review included only a small fraction of the glucose tracking apps available for download on the iTunes app store and Google Play. Methods used to select apps were subject to proprietary ranking algorithms by Apple and Google and thus the apps reviewed may not represent those of the highest quality as judged by more impartial

measures such as third-party ratings. To these authors' knowledge, however, no such rating system exists for diabetes apps. Nevertheless, there may have been apps of high quality that were not reviewed.

For the survey portion of the study, respondents on the HolaDoctor website constituted a convenience sample which may not reflect the entire Hispanic population. With its very large visitor base of over 1 million monthly unique users, the HolaDoctor website does, however, fairly represent the *online* Hispanics in the United States. Furthermore, evidence suggests that the majority of Latinos in the United States already use the internet in some fashion (Pew Research Center, 2013). Nevertheless, this does largely exclude the elderly, those with less than a high school education, and those who are predominantly Spanish-speaking (Pew Research Center, 2013), groups who shoulder a significant proportion of the diabetes burden within the Latino population as a whole. Given that 17% of the respondents in our survey reported providing care for a family member with diabetes, however, it is possible that the benefits of glucose tracking apps may extend beyond the immediate user to family members, specifically the elderly. Respondents living in countries other than the United States were also permitted to complete surveys, and this may also affect the generalizability of the study's conclusions given the inherent variation in social, cultural, and economic conditions between countries. The effect of this variation is likely to be minor, however, as the vast majority of responses (93%) came from the continental United States or Puerto Rico.

Finally, a number of the online surveys contained internally inconsistent responses. In particular, fewer than half of type I diabetics reported using insulin. Such incongruous responses may be due to respondents' confusion with the survey questions, though the authors suspect it stems more from a lack of knowledge and awareness regarding what type of diabetes they have,

if any.

Conclusion.

There is a significant need for glucose tracking apps targeted at Latinos. Given the high prevalence of diabetes in the Latino population and the CDC estimating a 50% lifetime diabetes risk for Latino children born in the year 2000 (Umpierrez, Gonzalez, Umpierrez, & Pimentel, 2007), apps designed specifically for this population will be needed to realize the full potential of mHealth to improve the lives of those affected by this disease.

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Tables and Figures

Figure 1. Screenshot of Diabetes App Lite by BHI Technologies, Inc.

Figure 2. Screenshot of Glucose Buddy by Azumio

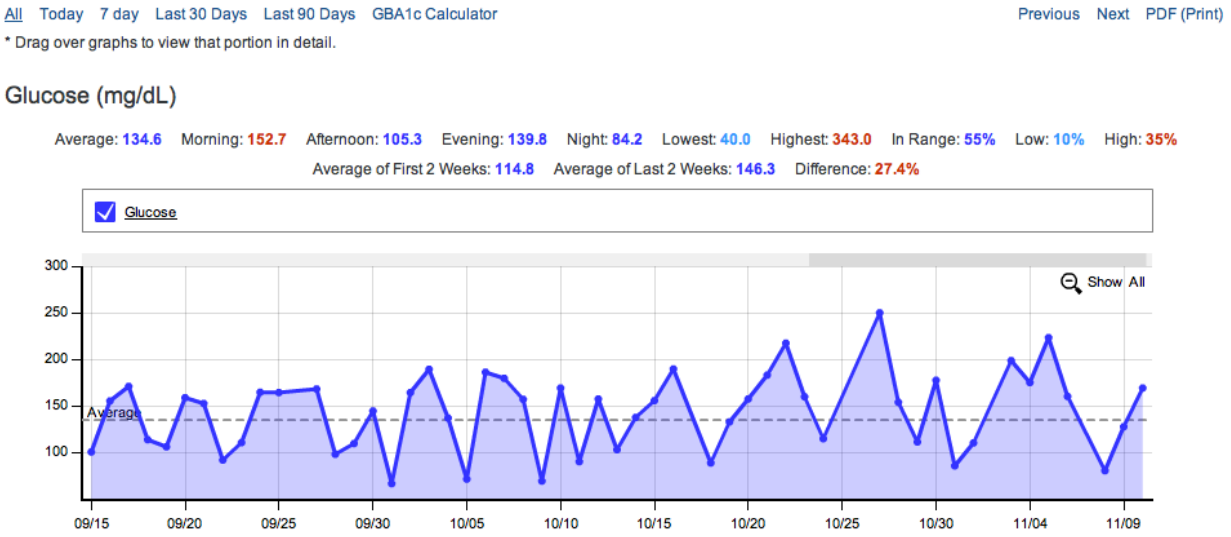

Figure 3. Prevalence of functionalities found in selected glucose tracking apps

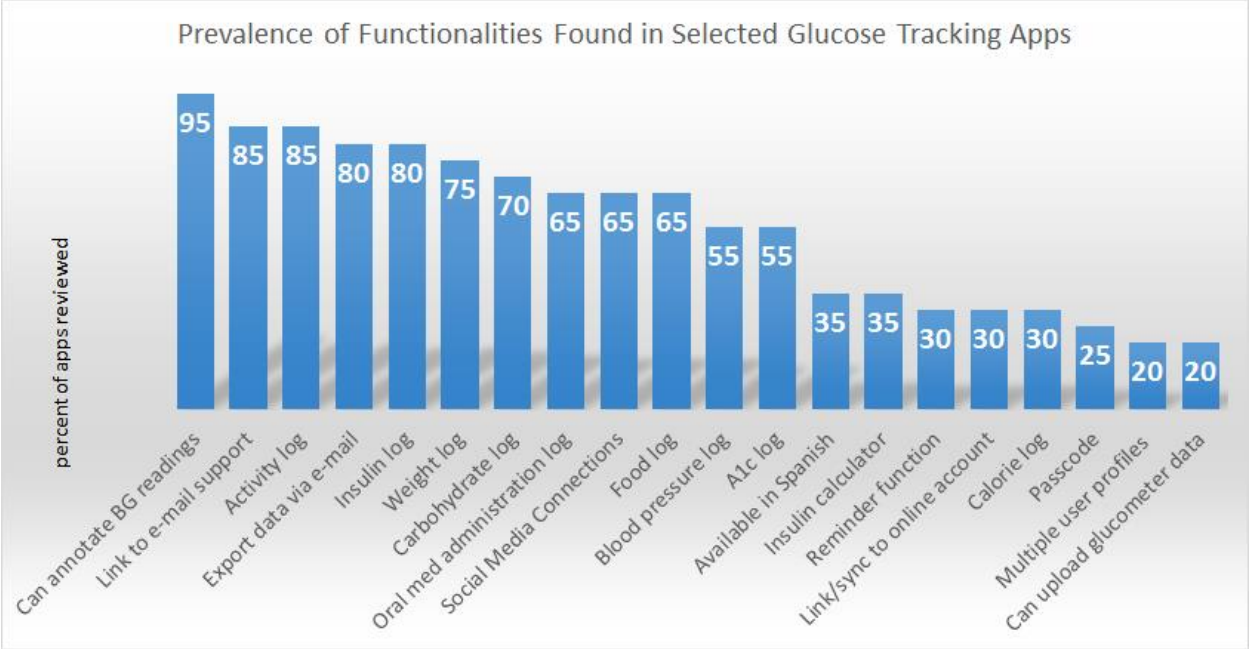

Table 1. Survey results, all respondents (n=1601)

	Number (%)
Country	
United States	1103 (68.89)
Puerto Rico	353 (22.05)
Mexico	46 (2.87)
Other[a]	45 (2.81)
Unknown	54 (3.37)
Do you have diabetes?	
Yes	588 (36.73)
No	491 (30.67)
I don't know	246 (15.37)
I take care of a family member with diabetes	276 (17.24)
Smartphone platform	
Android	815 (50.91)
Ios	415 (25.92)
Blackberry	17 (1.06)
Do not have smartphone	354 (22.11)

[a]Countries in this category included Argentina, Brazil, Canada, Chile, Colombia, Costa Rica, the Dominican Republic, Ecuador, El Salvador, Guatemala, Nicaragua, Panama, Peru, Spain, Switzerland, and Venezuela

Table 2. Survey results among patients reporting a history of diabetes (n=588)

	Number (%)
Country	
United States	415 (70.6)
Puerto Rico	133 (22.6)
Mexico	15 (2.6)
Other[a]	8 (1.4)
Unknown	17 (2.9)
Diabetes type	
Type I	74 (12.6)
Type II	408 (69.4)
Don't know	106 (18.0)
Do you use insulin?	
Yes	161 (27.4)
No	427 (72.6)
Do you use insulin? (type I	

only, n=74)	
Yes	29 (39.2)
No	45 (60.8)
Do you use insulin? (type II only, n=408)	
Yes	111 (27.2)
No	297 (72.8)
Do you use a diabetes app?	
Yes	18 (3.1)
No	570 (96.9)

[a]Countries in this category included Argentina, Brazil, Canada, Chile, Colombia, Costa Rica, the Dominican Republic, Ecuador, El Salvador, Guatemala, Nicaragua, Panama, Peru, Spain, Switzerland, and Venezuela

Table 3. Characteristics of app usage among diabetic respondents reporting use of diabetes apps (n=18)

	Number (%)
Language in which app is used	
English	4 (22)
Spanish	10 (56)
I don't know	4 (22)
How much did you pay for the app?	
Free	8 (44)
$0.99	1 (6)
$2.99	1 (6)
More than $3.00	3 (17)
I don't remember	5 (28)
Proportion of respondents reporting frequent use of the following documentation functionalities	
Oral medications	9 (50)
Blood glucose	8 (44)
Blood pressure	6 (33)
Diet-related	6 (33)
Weight	5 (28)
Exercise	4 (22)
HgbA1c	3 (17)
Insulin	3 (17)
None of these	4 (22)
Proportion of respondents reporting frequent use of the following reminder features	

Reminder to check blood glucose	9 (50)
Reminder to take medications	8 (44)
None	4 (22)
Information sharing	
Shares with physician only	10 (56)
Does not share with anyone	5 (28)
Diabetes forums	2 (11)
Facebook	1 (6)
Twitter	1 (6)

Chapter IV: Conclusion and Recommendations

Statement of principal findings.

Socioeconomic factors do not significantly limit access to mobile technology. Almost eighty percent of the respondents in our survey reported using a smartphone, a finding in line with previous research by the Pew Research Center which found that 76% of Latinos who use the internet access it on a mobile handheld device at least occasionally (2013). Despite statistics showing the median income of Hispanic families being a third less than that of their White counterparts (United States Census Bureau, 2012) and the share of Latinos with college degrees being less than half the national average (Pew Research Center, 2012), this population's use of mobile technology meets or exceeds the national average. This supports one of the basic premises of this research, namely that the potential for mobile health technology use in the Latino population justifies further research and investment.

Diabetes apps assume a certain level of health literacy which segments of the Latino population may not have. Flow sheets and graphing functionalities were nearly ubiquitous in the apps reviewed. While such features may accomplish the immediate objective of intimating a general pattern to the user's blood glucose control or lack thereof, the capacity to act on this information necessitates basic knowledge of diabetes, nutrition, and the user's diabetes medications—particularly when insulin is involved. Patients may not understand, for example,

that certain medications must be taken with food to avoid dangerous hypoglycemia, or that overly aggressive reduction in blood glucose may paradoxically lead to spikes (i.e. Somogyi Phenomenon) and the dangerously false impression of uncontrolled hyperglycemia. Such knowledge gaps are supported by our findings in which nearly half of self-reported type I diabetics reported not taking insulin and one in five respondents did not know into which diabetes type they had been classified. The potential benefits conferred by the use of this technology may be halted or even reversed in the absence of basic diabetes knowledge or access to healthcare providers.

Diabetes education is needed in apps for Latinos but is under-represented in diabetes apps. Diabetes education is fundamental to empowering app users to benefit from the numerous functionalities found in the hundreds of diabetes apps available, particularly for Latinos who lack diabetes knowledge and healthcare access compared to the rest of the U.S. population. The accessibility and portability of apps makes them an ideal vehicle for diabetes education in this underserved population, though diabetes education modules were largely absent from the diabetes apps reviewed.

Strengths and weaknesses of the study.

Strengths.

Glucose tracking app review. One of the primary benefits of our app review is its immediacy. In a period of only eight years, the number of diabetes apps has increased from a handful to over a thousand (University of Florida Health, 2015). These thousand apps undergo periodic updates, as do the operating systems responsible for running them. The operating system that runs the iPhone, for example (iOS), has undergone more than fifty updates since the iPhone's release in 2007 (Costello, 2015). The number of diabetes apps is therefore growing

rapidly and each app is changing over time. Our app review is one of the most recent to date and in this respect is more accurately representative of the current state of the diabetes app industry.

The impartial method by which the apps were selected for review is another strength. Rather than relying on expert opinion or professional consensus, we selected apps according to certain criteria. While these criteria were admittedly subject to the proprietary ranking algorithms of the Apple and Google app stores, few alternatives were available short of purchasing a membership to a website that sells download data on apps or ranks them based on reviews by non-healthcare professionals and/or non-diabetics. While the selection process was inherently flawed as a result, we still feel that the apps selected for review are an adequate representation of the current state of diabetes apps.

Online survey. The chief strength of our survey is the sheer number of respondents (over 1,600). Without such a high number we would not have been able to reach the small percentage of diabetes app users and evaluate their app preferences. It is also important to note that while internet users worldwide responded to our survey, the vast majority (over 90%) were from the United States or Puerto Rico. This increases the applicability of the findings to U.S. Latinos.

Weaknesses.

App review. The ranking algorithms used by Google and Apple change over time, and that which Google uses is not the same as that used by Apple. There is also evidence that app developers manipulate vulnerabilities in the algorithms to help their apps achieve a higher rank than they would otherwise (Lotan, 2015). Despite the measures taken to attempt complete objectivity in diabetes app selection, the lack of transparency by which Apple and Google rank apps, the dynamic nature of the algorithms, and their vulnerability to manipulation all decrease the overall quality and reproducibility of our review. It would not be unreasonable to assert that

only the wealthiest app developers could afford to artificially boost the rankings of their products in app stores. To the extent this may be true, this could have effectively transformed our review from that of the "best" diabetes apps to those that were the most expensively produced. Our app selection process was also non-randomized and comprised less than 2% of all diabetes apps available, further introducing bias into app selection.

*Online survey***.** Our survey does not equitably represent all Latinos, nor does it equitably represent all diabetic Latinos. It is arguably more representative of a smaller segment comprised of the health-conscious and technologically literate. To the degree that health consciousness and technological literacy are proxies for youth, educational attainment, acculturation, socioeconomic status, or a combination thereof, it is possible that we may have surveyed those who already have healthcare access and basic health literacy, essentially defeating the purpose of the study. The lack of diabetes knowledge and self-awareness implied by the survey responses, however, suggest otherwise. There is also great social, cultural, and economic heterogeneity within the Latino population itself which limits the applicability of our findings to any particular subgroup. Colombians, for example, are the most likely of the U.S. Hispanic population to have a college degree while Ecuadorians have the highest annual median household income (Pew Research Center, 2012); three times as many Hondurans lack health insurance compared with Puerto Ricans (2012). It may possible that the heterogeneity of our survey population is too great to draw any reliable inferences from our survey.

Our study in relation to other studies.

Strengths. As previously stated, the chief strength of this study is its immediacy. Computer technology—mHealth in particular—is a rapidly evolving field. As app developers update their products and software companies like Apple and Google update their operating

systems, any point-in-time examination of these apps becomes less useful with each passing month. Our study is not immune to this reality, but for the time being it is one of the most up to date studies on the subject of diabetes apps. Another strength of the app review is that apps from both major platforms (iOS and Android) were reviewed, whereas previous studies such as those by Rao and colleagues (2010) and Demidowich and colleagues (2012) limited their studies to one platform each. As can clearly be seen in our survey results, Latinos use both Apple and Android platforms. Our study also focuses on the use of diabetes smartphone apps in a particular subgroup, an approach that we feel is necessary to advance the field but is tedious and has been largely neglected in the literature.

Weaknesses. One of the primary objectives of any study on a novel product or treatment is to answer the question: "does it work?" Our study does not answer that question with respect to diabetes apps for Latinos, but rather operates on the unproven premise that diabetes apps *do* benefit Latinos and then goes on to propose how such benefits can be maximized. Older mHealth technologies such as SMS text messaging have been studied more thoroughly by researchers and yielded quantitative results for important chronic disease outcomes. Such research has yet to be undertaken for diabetes apps, and our study does little to further this cause. The positive findings yielded by studies of previous mHealth interventions, however, suggest that current and future mHealth technologies hold great promise for improving chronic disease management and outcomes. Another potential weakness of our study is the number of apps reviewed, a number significantly lower than the number reviewed by Chomutare and colleagues (2011) or by Demidowich and colleagues (2012). Nevertheless, we felt that reviewing ten apps from each platform was sufficient for our purposes and the most optimal use of our limited time and resources. We also limited our app search to online app stores, unlike Chomutare and

colleagues (2011) who searched online journal databases in addition to app stores. While this may have also limited the scope of our research, our intention from the beginning was to study commercially developed diabetes apps which comprise the vast majority of apps currently in use. Finally, survey respondents constituted a convenience sample comprised of technology-literate individuals which may misrepresent the Latino population by overestimating smartphone ownership and diabetes app usage in this population. Elderly, foreign-born and low-income Latino subpopulations who face some of the greatest obstacles to diabetes care may not be adequately represented.

Implications for clinicians and policymakers. mHealth is going to play a major role in healthcare delivery in the future. With this technology, patients and insurance companies can benefit from improved chronic disease outcomes and cost savings. As further studies accumulate demonstrating the capacity for diabetes apps to improve diabetes self-management and blood glucose control, it is likely that health insurance companies will cover the cost of their customers purchasing these technologies and physicians will integrate them into routine clinical care. One of the fundamental questions facing the federal government and insurance companies is how this technology is to be classified and regulated. Competing legislation has already been introduced in the form of the SOFTWARE and PROTECT acts, each of which attempts to risk-stratify novel medical technologies and outline appropriate regulatory oversight. As of the time of the writing of this paper, the FDA's regulatory focus is on apps that are an "extension of" other medical devices (e.g. apps with Bluetooth glucometer connectivity), apps that "transform a mobile platform into a regulated medical device" (e.g. apps designed for glucose strip readers directly attached to smartphones), and apps that perform "patient-specific analysis" and "patient-specific diagnosis" (e.g. apps that calculate insulin dosing). Balancing the risk to the patient with the

potential benefit of these technologies will necessitate further careful research, as the degree of regulation deemed necessary will affect development costs and will in turn decide whether individuals will be able to compete with companies in the diabetes app market.

Clinicians will also need to become more familiar with apps in order to serve their patients. The confines of a routine 15-minute visit will require healthcare providers to efficiently access, analyze, and interpret patient data on these apps. Many if not most physicians are not prepared to do this. Transferring or documenting the data provided by the app in the patient's chart is another hurdle that clinicians will face and the developers of electronic medical records systems (EMRs) will need to confront. Indeed, the very nature of the patient-physician relationship will be fundamentally altered by these technologies and patient, provider, and insurer will all be forced to adapt or be left behind.

Fortunately, such challenges also present opportunities for Latinos to reduce cultural and financial barriers. Without saying a word, Latinos can communicate with the doctor through the use of flow sheets, graphs, charts, and other documentation and analytical functionalities present on most diabetes apps. By no means will this obviate the need for culturally sensitive providers and interpreters, but diabetes apps can enhance communication by serving as a shared reference point between provider and patient. Patients may also save on transportation to and from health clinics and perhaps even avoid co-pays by communicating with their providers over the internet. Time away from work would also be reduced, an issue of particular importance to employed Latinos of whom 60 percent receive zero paid sick days (National Partnership for Women & Families, 2013).

Implications for researchers and app developers. For diabetes apps to benefit Latinos, they should be (1) educational and (2) easy to use. Despite their importance, educational

modules are largely lacking in current diabetes apps. Further research should clarify the most effective methods and media with which to educate Latinos about their diabetes. Developers should then apply these findings to the design of their apps. Ease of use can be increased by (1) reducing the burden of data entry and (2) maximizing usability. The burden of data entry can be addressed chiefly by providing connectivities to medical devices such as glucometers and blood pressure cuffs, eliminating the need for users to transfer the data manually from the medical device into their smartphone. To maximize usability, apps should be available in both English and Spanish, use simple language at a basic reading level, and adhere to basic visual design guidelines such as those provided by usability.gov (2015). Developers should also carefully consider which functionalities yield the greatest benefits to patients and how many to include in their apps, as this number has been shown to affect usability (Rao, et al., 2010).

Most importantly, further research needs to be undertaken into what extent and under what conditions diabetes apps improve diabetes outcomes, both in the short-term (e.g. HgbA1c reduction) and long-term (i.e. reduction in morbidity and mortality). In particular, studies should look at whether apps can improve blood glucose control in patients with no healthcare access or if doctor-patient communication using app-generated data could substitute for face-to-face visits. Cost savings from these approaches should also be examined. Using these findings, both private insurers and state and federal governments can make informed policy decisions about if and to what extent diabetes apps should be reimbursed.

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Appendix

Appendix A: Review of selected glucose tracking apps

iPhone										
App Name	Glucose Buddy	Diabetes App Lite	Diabetes Pal	Diabetes Companion	iBG Star Diabetes Manager	Diabetes App	Diabetes Tracker	Glucose Buddy Pro	Track3	Glucose Companion
Company	Azumio	BHI Technologies	Telcare, Inc.	mySugr GmbH	Sanofi-Aventis	BHI Technologies	MyNetDiary, Inc.	Azumio	Coheso, Inc.	Maxwell Software
Cost	free	free	free	free	free	$6.99	$9.99	$6.99	$5.99	$1.99
Available in Spanish	no	no	no	yes	yes	no	no	no	no	no
Logs										
Blood Glucose	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Medications:										
oral/subcutaneous (non-insulin)	yes	yes	yes	no	no	yes	yes	yes	yes	no
insulin	yes	yes	yes	yes	yes	yes	yes	yes	yes	no
Activity	yes	yes	yes	yes	yes[b]	yes	yes	yes	yes	no
Weight	no	yes	yes	no	no	yes	yes	yes	yes	yes
Blood pressure	no	no	yes	no	no	yes	yes	yes	no	no
A1c	yes	no	yes	no	no	no	yes	yes	no	no
Nutrition:										
Foods	yes	yes	yes	yes	no	yes	yes	yes	yes	no
Calories	no	yes	no	no	no	yes	yes	no	yes	no
Carbohydrates	no	yes	yes	yes	yes	yes	yes	no	yes	no
reminder function	no	no	no	no	no	no	no	no	no	yes
link/sync to online account	yes	no	yes	no	no	no	yes	yes	no	no
ability to annotate BG readings	yes	yes	yes	yes	yes[a]	yes	yes	yes	yes	yes
link to e-mail support	yes	yes	yes	yes	no	yes	no	yes	yes	yes
passcode	no	yes	no	yes	no	yes	yes	no	no	yes
insulin calculator	no	no	no	no	no	no	no	no	yes	yes
multiple user profiles allowed	no	no	no	no	no	no	no	no	no	yes
export data via e-mail	yes	no	yes	yes	yes	yes	yes	yes	yes	yes
can upload data from glucometer	no	no	yes	no	yes	no	no	no	no	no

[a] manual text entry not available, must select from list of available phrases

[b] only able to specify whether physical activity was light, medium, heavy, or missed altogether

[c] must select from a list of medications

	Android									
App Name	**Glucose Buddy**	**Diabetes- Glucose Diary**	**OnTrack Diabetes**	**My Diabetes**	**Diabetes Journal**	**Health Tracker Full**	**Glucose Meter- Diabetes**	**Track3 Diabetes Tracker**	**DiaLog: Diabetes Logbook**	**BG Monitor Diabetes Pro**
Company	Azumio	Klimaszewski Szymon	Medivo	Rossen Varbanov	Suderman Solutions	Lior Ben Oved	Francisco J Belchi	Coheso, Inc.	David Froehlich	Gordon Wong
Cost	free	free	free	free	free	$2.84	$2.50	$5.99	$4.99	$2.00
Available in Spanish	no	yes	yes	yes	yes	no	yes	no	no	no
Logs										
Blood Glucose	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Medications:										
oral/subcutaneous (non-insulin)	yes	no	yes	yes	yes	no	no	yes[c]	yes	no
insulin	yes	no	yes	yes	yes	no	no	yes[c]	yes	yes
Activity	yes	no	yes	yes	yes	no	yes	yes	yes	yes
Weight	yes	no	yes	yes	yes	yes	yes	yes	yes	no
Blood pressure	yes	no	yes	yes	yes	yes	yes	no	yes	no
A1c	yes	no	yes	yes	yes	yes	yes	no	yes	no
Nutrition:										
Foods	yes	no	yes	yes	no	no	no	yes	yes	no
Calories	no	no	yes	no	no	no	no	yes	no	no
Carbohydrates	no	no	yes	yes	yes	no	yes	yes	yes	yes
reminder function	yes	no	yes	yes	no	no	no	no	yes	yes
link/sync to online account	no	no	no	no	no	no	no	yes	yes	no
ability to annotate BG readings	yes	yes	yes	yes	yes	yes	no	yes	yes	yes
link to e-mail support	yes	yes	yes	yes	yes	yes	no	yes	yes	yes
passcode	no	no	no	no	no	no	no	no	no	no
insulin calculator	no	no	no	yes	no	no	yes	yes	yes	yes
multiple user profiles allowed	no	yes	no	no	yes	yes	no	no	no	no
export data via e-mail	yes	yes	yes	yes	no	yes	no	yes	no	yes
can upload data from glucometer	no	no	no	yes	no	no	yes	no	no	no