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Abstract

Although smartphones bear potential to improve diabetes self-management, the reach of smartphones in diabetic populations remains uncertain. Using survey data from the Pew Research Center, we compared smartphone use in individuals with and without diabetes, and determined factors associated with smartphone use among those with diabetes. Of the 2989 adults surveyed, 1360 were smartphone users, and 332 individuals had diabetes. Compared to individuals without diabetes, adults with diabetes were less likely to be smartphone users (relative risk of 0.43, 95% CI 0.31 to 0.54) even after adjusting for age, race, ethnicity and socioeconomic status (adjusted RR of 0.78, 95%CI 0.57-0.98). Among individuals with diabetes, high income, younger age and online health information seeking were associated with higher smartphone use. While smartphones can reach subgroups for diabetes care and prevention (racial/ethnic minorities, newly diagnosed individuals), studies are needed to understand this current difference in smartphone use.

Introduction

Smartphones have shown potential in improving diabetes self-management. The rapid adoption of smartphones[1] and the rising prevalence of diabetes[2] have led to the development of a large array of supportive applications aimed at improving diabetes self-management in daily tasks and choices: they help learn about diabetes and its management, track health parameters with graphs and data sharing options, and allow calendaring for daily tasks or annual screening procedures[3, 4]. Seven out of ten American adults track a health parameter such as weight, exercise or sleep[5], and one in five smartphone users having a health app on their device[6]. Although treatment goals are well established[7], less than one fifth of patients achieve HbA1c, blood pressure and LDL-cholesterol goals[8]. A meta-analysis of 22 trials assessing the effect of mobile phone interventions on glycemic control showed a reduction of HbA1c of 0.5% over a median of 6 months' follow-up duration[9]. A randomized controlled trial with a smartphone application that offers automated clinical coaching based on patient-reported data and that supports data-sharing with care providers, showed a 1.2% greater decrease in HbA1c with web- and mobile-based tools compared to usual care over a year (1.9% in web- and mobile-based group vs 0.7% in usual care group, $p<0.001$)[10]. Early studies suggest promise of effective support for diabetes self-management with smartphone applications.

The uptake of smartphone applications depends on consumer access to the devices, as well as on human-computer interaction issues including sufficient functionality and usability[11]. Although studies have characterized who has diabetes and smartphone users, we do not have a clear understanding of the socio-demographic characteristics associated with smartphone use among individuals with diabetes. The exponential growth in smartphone adoption has reached more than half of US adults, who are from all demographic groups[1, 12]. The diffusion of innovation theory[13] claims that age predicts the adoption of technologies, with the younger population adopting new technologies before the older population. Although higher income and higher education are strong predictors of all-age smartphone adoption, younger adults seem to be less affected by these variables. Asians and African Americans are more likely to be smartphone users than Caucasians, and African-Americans are also more likely to have health applications on their phone than other racial/ethnic groups (15% of African Americans vs 7% of whites and 11% of Latinos). This difference is particularly relevant, as these groups also have a higher prevalence of diabetes (11.8% of Hispanics, 12.6% of non-Hispanic Blacks compared to 8.3% of the U.S. population)[14, 15], with lower glycemic control in African Americans and Hispanics. Diabetes prevalence is also higher with increasing age (13.7% in the 45-64 year old group, and 26.9% in those over 65 years old)[15].

The aim of this study is to identify the reach of use smartphones among individuals with diabetes and to examine the socio-demographic profile of smartphone users with diabetes. Although many smartphone and tablet applications to support diabetes self-management are available, characteristics of smartphone users in the targeted population remain unclear. These characteristics are important, if developers desire to tailor mobile apps to the users' needs.

We hypothesized that compared to individuals without diabetes, individuals with diabetes will be less likely to use smartphones, due to older age and lower socioeconomic status (SES)[15]. We also hypothesized that individuals with diabetes would be more likely to use smartphones if they have a higher level of education, younger age, non-White race and high income[16]. Finally, as many of the current diabetes application features involve data tracking and interpretation[3, 4], we hypothesized that smartphone use among diabetics would be associated with higher self-monitoring. Understanding who uses and does not use smartphones among patients with diabetes can inform future diffusion and design of diabetes applications.

Methods

Population

This cross-sectional study uses a survey dataset of the Pew Research Center collected between August 7 and September 6, 2012. This data was collected initially to describe the use of mobile technology for health[17]. Researchers conducted a nationwide survey in the U.S. using phone interviews in English and Spanish of 3,014 adults >18 years old (1,808 landline and 1,206 mobile users). Participant selection was by random digit dial of both landline and cellphone numbers. For landline sample, the interviewers followed a systematic respondent selection technique that closely mirrors the population in terms of age and gender when combined with cellphone sample. Both samples were oversampled for Black and Hispanic respondents. Response rates were 11.5% for landlines and 6.6% for cell phones (total of 58,848 landlines and 32,129 cell phones dialed). The survey weights supplied with the survey[17] were used to generate population level estimates. The margin of sampling error was ±2.4 percentage points for the complete set of weighted data. This survey was conducted by Princeton Survey Research Associates International and sponsored by the Pew Research Center's Internet & American Life Project and the California HealthCare Foundation. This current study was conducted with the permission of the Pew Research Center's Internet & American Life project.

Survey

This phone survey was created to study how cell phones, particularly smartphones, are used to look for health information. It included questions about self-reported health conditions (overall health and common chronic diseases), tracking behaviors (in particular of weight, diet, exercise, and blood pressure), use of social networks, and searching for online health information about specific diseases or treatments, heath insurance, or more general food and drug safety information. The complete interview (26 questions) can be found online[18].

Analysis

The primary analysis (Table 3) compared the use of smartphones between diabetic and non-diabetic participants using unadjusted and adjusted weighted logistic regression models. Smartphone users were defined as any user of a smartphone, including those who had both a landline and a smartphone. Non-smartphone users were all other participants, and included feature phone (cell phone that is not a smartphone) users and landline-only users. The covariates in the logistic regression models were defined a priori, with an age-adjusted model and the full model (age, measures of socio-economic status, race, ethnicity). Age was hypothesized to be the main confounder of smartphone use and diabetes. The other demographic confounders are based on results from market studies of smartphone use. In these models, age, race, income and education were categorical variables, as presented in tables 1 and 2.

The secondary analysis (Table 4) used a multivariate logistic regression model among diabetics to estimate predictors of smartphone use. All variables of interest were chosen a priori by the investigators and entered together in the model: age (categorical), race and ethnicity, education and income (all binary). For this secondary analysis, we used a binary variable combining race and ethnicity, as well as binary variables for education and income to avoid having too few events per variable. Education was defined using a threshold of high school completion. The cutoff for income level of $50,000 per year was based on the annual median household income in the U.S. of $50,502 in 2011[19]. The second model for this analysis also included online health information seeking as a proxy for patient engagement, and health tracking (both binary).

All analyses and characteristics of the sample were computed from the weighted sample after exclusion of missing diabetes or smartphone values (N=2989). The percentage of complete cases was 78%. Missing covariate data were infrequent (≤1.8%) other than for income (18.5%). Missing data were multiple-imputed with 25 imputed datasets using imputation by chained-equations[20]. The imputation model included the covariates used in all our analysis (with dependent variables), as well as three auxiliary variables: state, use of urgent care in the past 12 months and self-reported health. Categorical variables were compared using Chi-Square tests. P values from regression models were derived from Wald tests with robust standard errors. A p-value <0.05 determined statistical significance. Residual confounding was assessed by testing the effect modification of diabetes by age group. As smartphone use is not a rare event, odds ratios do not approximate relative risks. To avoid misinterpretation of the results, we presented our results after conversion to relative risks using the margins function[2121212120] of Stata 11 (Stata Corporation, Texas).

Results

We describe the diabetic and non-diabetic populations in our sample (Table 1), with weighted descriptive analyses. Among the 2991 respondents, 332 had diabetes (weighted proportion of 11.1%). Individuals with diabetes were significantly older than non-diabetic participants (mean age of 59.9y vs 45.5y, p<.001, Table 1). They also had more comorbidities (hypertension, congestive heart failure and other chronic diseases such as asthma or cancer). Gender and ethnicity were not different, but more participants with diabetes were of Black race than participants without diabetes (16.9% vs 12.7%). Socio-economic status was lower in the diabetic group, with fewer insured participants, lower educational attainment, a lower income and a higher prevalence of unemployment. Compared with non-diabetics, individuals with diabetes had a significantly higher feature phone use (50.6% vs 38.3%, p<.001 Table 1) and a lower smartphone use (20.7% vs 48.6%, p<.001). About half of the patients with diabetes used email and Internet, compared with over three quarters of individuals without diabetes. Moreover, five out of six participants with diabetes tracked at least one health parameter (diet, weight, carbohydrates, etc.), compared with two thirds of non-diabetics (p<.001). Individuals with diabetes had a lower use of health applications on smartphones (3.8% vs 10.0%, p=.002).

In Table 2, we report the characteristics of smartphone users in our sample (both diabetic and non-diabetic individuals included) compared with non-smartphone users. This latter group includes individuals who use feature phones and/or landlines. The sample comprised 1360 smartphone users (weighted proportion 45.5%) and 1629 non-smartphone users (1185 feature phone users and 444 individuals with only landlines, weighted proportions 39.6% and 14.8% respectively). The landline only population was older, with more comorbidities: they had the highest prevalence of diabetes (21.4%), compared with feature phone users (14.2%) and smartphone users (5.0%). They had a higher proportion of Caucasians (81.2%) and Hispanics (16.1%) than the feature phone and smartphone users, and had lower educational attainment. They had lower use of email and Internet. Gender was not significantly different among these groups.

Table 1. Weighted comparison of individuals with and without diabetes in the study population

	Diabetes	**No diabetes**
Total N	332 (11.1%)	2657 (88.9%)
Mean age (SD, 95% CI)*	59.9y (1.1, 57.8-62.0)	45.5y (0.4, 44.7-46.4)
18-35 y	8.8%	34.6%
36-50 y	16.8%	28.2%
51-64 y	35.4%	21.4%
65-80 y	31.5%	11.4%
>80 y	7.5%	4.4%
Male	53.5%	50.9%
Comorbidities:		
Hypertension*	67.1%	20.1%
Heart disease*	27.5%	4.9%
Other chronic disease*	82.9%	38.0%
Race		
White	70.2%	74.0%
Black	16.9%	12.7%
Asian	1.6%	3.0%
Other race	11.3%	10.3%
Ethnicity		
Hispanic	15.8%	13.2%
Health insurance*		
Uninsured	11.2%	18.5%
Medicaid	11.2%	7.4%
Medicare	24.3%	7.1%
Private insurance	50.8%	64.4%
Attained education*		
No high school	20.7%	10.4%
High school	62.1%	59.2%
College or higher	17.2%	30.4%
Annual income*		
<30,000$	60.2%	36.4%
30,000-99,999$	36.0%	47.1%
≥100,000$	3.8%	16.5%
Employed*	30.3%	58.0%
Feature phone users*	50.6%	38.3%
Smartphone users*	20.7%	48.6%
Use of Internet*	53.4%	81.6%
Use of email*	47.6%	75.4%
Tracks any health parameter*	84.3%	64.9%
Use of health app on smartphone*	3.9%	10.05

*p≤.001

Table 2. Weighted comparison of smartphone users and non-smartphone users (landline or feature phones users)

	Smartphone users	**Not smartphone users**
Total N	1360 (45.5%)	1629 (54.5%)
Landline only (% total population)	-	444 (14.8%)
Diabetes (%)*	5.0%	16.1%
Mean age (SD, 95% CI)*	38.9 y (0.5, 38.0-39.8)	54.0 y(0.6, 52.8-55.2)
18-35 y	46.5%	19.4%
36-50 y	32.9%	21.9%
51-64 y	16.0%	28.7%
65-80 y	3.8%	21.9%
>80 y	0.7%	8.1%
Male	50.1%	52.1%
Comorbidities:		
Hypertension*	14.7%	34.1%
Heart disease*	3.1%	11.0%
Other chronic disease*	30.3%	53.5%
Race*		
White	69.5%	77.0%
Black	14.0%	12.5%
Asian	5.1%	1.0%
Other race	11.4%	9.5%
Ethnicity		
Hispanic	14.7%	12.6%
Health insurance*		
Uninsured	17.7%	17.6%
Medicaid	5.4%	9.9%
Medicare	2.6%	14.3%
Private insurance	72.2%	55.2%
Attained education*		
No high school	5.5%	16.5%
High school	56.0%	62.4%
College or higher	38.4%	21.1%
Annual income*		
<30,000$	27.7%	48.5%
30,000-99,999$	49.6%	42.8%
≥100,000$	22.7%	8.7%
Employed*	72.3%	40.4%
Use of internet*	97.7%	62.4%
Use of email*	92.3%	55.7%
Tracks any health parameter	67.9%	66.3%

*p<.001.

(The smartphone user group includes users of both smartphone and landline phones)

Compared to White participants, Asian participants had a significantly higher use of smartphones (Table 2). The smartphone population also had significantly higher income, employment rate and higher educational attainment than the non-smartphone population. The proportion of uninsured did not differ with smartphone use. Finally, use of emails and Internet was almost universal in the smartphone group (92% and 98% of individuals, respectively), compared to less than two thirds of the non-smartphone group. Two thirds of the participants tracked some health parameter, regardless of the type of phone technology.

The results of the primary analysis comparing the use of smartphone between diabetic and non-diabetic participants are presented in Table 3. In the unadjusted analysis, individuals with diabetes were less likely to use smartphones compared with those without diabetes (RR 0.43, 95% CI 0.31 to 0.54, p<.001). After adjusting for age, individuals with diabetes were still less likely to be smartphone users compared with those without diabetes (RR 0.58, 95%CI 0.40 to 0.75, p<.001). In the full model that adjusted for race, ethnicity, income and education level (potential confounders), participants with diabetes remained significantly less likely to be smartphone users compared with those without diabetes (RR 0.78, 95% 0.57-0.98, p=0.05). In this multivariate model, we also observed that Blacks, Asians and Hispanics were more likely to use a smartphone than Caucasians and non-Hispanics, respectively. We also found strong evidence that a higher income and education attainment was positively associated with smartphone use. There was no significant residual confounding by age in the adjusted analysis.

The results of the secondary analysis of predictors of smartphone use among individuals with diabetes are shown in Table 4. In the multivariate model 1, younger age and higher income were strongly associated with smartphone use, whereas race/ethnicity and education were not. Model 2 further explored online health seeking behavior and health tracking behavior. Individuals who sought health information online were more likely to be smartphone users (RR 3.68, 95% CI 1.06-6.30, p<.001). The individuals who tracked health parameters, however, were *less* likely to be smartphone users (RR of 0.62, 95%CI 0.36-0.88, p=0.04).

Table 3. Unadjusted and adjusted RR comparing individuals with diabetes to individuals without diabetes for smartphone use (N=2989)

	Unadjusted RR (95%CI) p-value	**Age-adjusted** RR (95%CI) p-value	**Full model** RR (95%CI) p-value
Diabetes	0.43 (0.31-0.54) <.001	0.58 (0.40-0.75) <.001	0.78 (0.57-0.98) 0.05
Age		<.001	<.001
18-35 y		(Ref)	(Ref)
36-50 y		0.81 (0.70-0.92)	0.82 (0.74-0.90)\
51-64 y		0.45 (0.38-0.53)	0.48 (0.39-0.57)
65-80 y		0.38 (0.13-0.23)	0.24 (0.17-0.31)
>80 y		0.09 (0.04-0.15)	0.10 (0.04-0.17)
Race			<.001
White			(Ref)
Black			1.30 (1.04-1.56)
Asian			2.10 (1.45-2.75)
Other race			1.07 (0.75-1.39)
Hispanic			1.30 (1.02-1.57) 0.02
Annual income:			<.001
<30,000$			(Ref)
30,000-99,999$			1.65 (1.31-1.99)
≥100,000$			2.63 (1.98-3.28)
Attained education:			<.001
No high school			(Ref)
High school			1.82 (1.14-2.49)
College or higher			2.52 (1.53-3.51)

Table 4. Multivariate predictors of smartphone use among individuals with diabetes (N=332)

Covariates	**Model 1**			**Model 2**		
	RR	**95%CI**	**p-value**	**RR**	**95%CI**	**p-value**
Age 18-35 y	(Ref)		<.001	(Ref)		<.001
Age 36-50 y	0.37	(0.15-0.60)		0.50	(0.18-0.83)	
Age 51-64 y	0.28	(0.12-0.44)		0.39	(0.15-0.63)	
Age >65 y	0.13	(0.04-0.22)		0.26	(0.08-0.44)	
Non-White or Hispanic	1.42	(0.77-2.06)	0.13	1.41	(0.82-2.00)	0.10
High school education	1.22	(0.51-1.93)	0.50	0.96	(0.45-1.47)	0.88
Annual income > 50,000$	3.09	(1.35-4.84)	<.001	2.34	(1.13-3.54)	0.002
Seeks health information online				3.68	(1.06-6.30)	<.001
Tracks any health parameter				0.62	(0.36-0.88)	0.04

Discussion

In our nationwide sample, we found that individuals with diabetes were less likely to be smartphone users compared with individuals without diabetes, even after adjusting for potential confounding by age, SES, race and ethnicity.

The pattern of lower use among the older population is consistent with market studies on smartphone adoption[1, 22]. Although early evidence supports the long-term effectiveness of mobile technologies in diabetes self-management with improved HbA1c values after 6 months[9] and 12 months[10], our results suggest that these technologies might not be appropriate for all individuals, and efforts to improve standard care in diabetes self-management should continue to include more traditional contacts with patients including in-person and standard telephone communications.

Understanding lower smartphone use among individuals with diabetes is important, as healthcare delivery systems are likely to move towards a higher use of smartphone applications for diabetes self-management. Diabetes, its long-term complications and related comorbidities can lead to physical and cognitive impairments, such as lower dexterity from neuropathy or visual impairments. All these unmeasured factors are barriers to smartphone use, and are all accentuated by older age. Despite the slow increase in smartphone uptake among older adults, the very rapid uptake among younger adults may accentuate the age gap in smartphone use. The trend towards larger screens of newer devices (phablets, mini-tablets and tablets) and improved usability are promising approaches to address visibility and dexterity impairments related to diabetes and age[23, 24]. Finally, care-providers might also have a role to play in diffusing diabetes applications to patients who already use smartphones[25], as they already provide guidance for websites and online communities to their patients[26]. Our findings support further research on understanding the differences in the use of smartphone use among patient with diabetes.

The 51 to 64 year-old age group may benefit the most from smartphone-based interventions for diabetes, as it is the second fastest growing age group for smartphone uptake[12]. We found that one in six individuals in this age group currently used smartphones. With over a million individuals from this age group newly diagnosed with diabetes each year in the U.S.[2], the potential reach of smartphone-based interventions should not be overlooked, particularly for the early stages of disease[27]. Smartphone interventions have the potential to lower HbA1c values effectively, (e.g., mean HbA1c reduction of 1.9% in the smartphone group vs 0.7% in the usual care group (P=0.001) over 12 months)[10]. Any 1% reduction in HbA1c is associated with significant reduction of the risk for myocardial infarction (14%) and stroke (12%)[28]. Furthermore, not only does the benefit of HbA1c reduction increase over time, the reduction in all-cause mortality is greater when the HbA1c reduction occurs early in the disease[29].

As smartphone use is highest among young adults, it may offer unique opportunities for early diabetes self-management or diabetes prevention. Most diabetes applications provide tracking tools to monitor health parameters, and can guide early disease management, making these tools particularly useful at early stages of disease)[3, 27]. In addition, the reach of smartphones among racial/ethnic minorities might allow early prevention by supporting behavior change in this subpopulation with higher prevalence of early type 2 diabetes, in particular among adolescents.

In contrast to the age gap, smartphones have greater potential to help bridge the typical “digital divide” in Internet and computer access in racial and ethnic groups. The higher smartphone use by Blacks, Asians and Hispanics compared to Whites and non-Hispanics, reflect the importance of race and ethnicity for smartphone use[1, 16]. This finding has two important implications: (1) smartphones might be a new approach to improve access to high quality care for diabetes in racial/ethnic minority groups, and (2) future diabetes applications need to take cultural differences into consideration in their design. For instance, only a few diabetes applications currently offer the option of Spanish. Also, most applications or websites do not include options for cultural preferences in their food plans. One possible design implication could be to integrate more culturally adapted nutrition facts in smartphone applications to facilitate the adoption and adherence to diabetes-friendly food plans in this racial/ethnic minority groups.

Contrary to our hypothesis of smartphone use for health tracking, we found that individuals were less likely to be a smartphone user if they monitored their own health. Nearly two thirds of our participants tracked some health parameter, regardless of phone type. Individuals with diabetes predominantly have type 2 diabetes and do not use insulin, and therefore do not require highly intensive health tracking. In a prior study, patients seemed to categorize many of their health results as normal or abnormal, rather than recall the exact values, and therefore are content to check with little or not tracking[27, 30]. They tended to use traditional tracking methods (pen and paper, or websites) according to a recent survey[26]. Smartphones offer a wide range of features, and are not primarily adopted for health tracking purposes. This underlines the gap in assessing overall smartphone use rather than the use of diabetes-related applications. Furthermore, there is a delay in the diffusion of diabetes applications among smartphone users, and the use of pervasive technologies in smartphones to effortlessly track health.

Strengths and Limitations

One of the strengths of this paper is its secondary use of a dataset collected to study mobile health. It uses a random sample of landline and cellphone users from the national U.S. population, without targeting any disease in particular. This helps avoid the bias related to successful diabetes self-management. The survey was also conducted in two languages, English and Spanish, which facilitate participation from the rapidly growing Hispanic population.

Although the prevalence of diabetes in this sample (11.1% after weighting) is comparable to the prevalence of diabetes among U.S adults, a limitation of this study is its use of self-reported diabetes, as undiagnosed diabetes is estimated to be about a third of cases in the United States[2]. This limitation could contribute to the lack of association seen between smartphone use and race/ethnicity among individuals with diabetes. Furthermore, the survey did not differentiate between type 1 and type 2 diabetes. Yet type 2 is more prevalent among older adults and in lower SES populations[15]. The low survey response rate for both the landline and cellphone samples may also limit the generalizability of our findings. Moreover, this dataset only provided information about self-reported diabetes, without information about type of disease. Future studies should explore the association between disease duration, severity (HbA1c and comorbidities) and type of treatment (insulin use) and smartphone use.

Implications

Smartphones have generated great interest for patient empowerment, and bear potential in improving diabetes self-management in particular. Although the exponential growth of smartphone adoption now affects all age groups, this growth remains moderate among older individuals with lower income. Individuals with diabetes are older and have lower income than the general population: they therefore remain less likely to have a smartphone than individuals without diabetes. So although it is important for clinicians to be familiar with smartphone tools for diabetes, especially for subgroups of younger, newly diagnosed individuals or those from racial/ethnic minorities, we underline the importance of pursuing efforts to improve traditional diabetes care (in-person visits and phone calls) at this time. Further research is needed to understand this gap in smartphone adoption in the diabetic population, both in terms of access to the devices as well as for usability and design (font and screen sizes, for example).

Conclusion

This study is, to the best of our knowledge, the first report on the characteristics of smartphone users in a population of patients with diabetes. Compared to individuals without diabetes, smartphone use remains significantly less likely among individuals with diabetes. Since smartphones have the potential to improve self-management support for diabetes care, further research is needed to better understand this gap in smartphone use, in particular to address diabetes- and age-related differences. Our findings also emphasize the potential of smartphones to help prevent diabetes in younger adults, and to improve access to care for racial and ethnic minorities.

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