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ORIGINAL RESEARCH

Use of self-monitoring tools in a clinic sample of adults with type 2 diabetes

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ABSTRACT

Self-monitoring is an effective strategy for chronic disease management; many readily available mobile applications allow tracking of diabetes-related health behaviors but their use has not yet been integrated into routine clinical care. How patients engage with these applications in the real world is not well understood. The specific aim of this study is to survey adults with type 2 diabetes (T2D) regarding self-monitoring behaviors, including mobile application use. In 2015, we surveyed an adult diabetes clinic population ($n = 96$) regarding self-monitoring behaviors: diet, physical activity, weight, and blood glucose. Self-monitoring with any method ranged from 20–90 %. About half of the participants owned smartphones; few had mobile applications. The most common app-tracked behavior was physical activity, then weight and diet. Despite numerous available mobile health-tracking applications, few T2D adults from our sample used them, though many reported self-monitoring with other methods.

KEYWORDS

Diabetes, mHealth, Self-monitoring, Smartphone

Implications

Practice: Diabetes care providers and mobile application developers have key roles to play in ensuring that applications meet evidence-based clinical recommendations, and in narrowing the gap between application availability and real-world use among adults with type 2 diabetes.

Policy: Greater emphasis should be placed on user-friendly applications that adhere to evidence-based clinical guidelines and integrate with diabetes healthcare delivery (e.g., transmitting blood glucose meter readings without need for human data entry).

Research: More research in clinical settings is needed to determine how best to implement mobile application tracking for adults with type 2 diabetes, and to identify which health behaviors and outcomes are most beneficial for this population to self-monitor.

INTRODUCTION

Roughly 29.1 million people in the USA have diabetes; the vast majority of diabetes cases (90 %) are type 2 diabetes (T2D) [1]. Diabetes progression can lead to complications (e.g., retinopathy, nephropathy, neuropathy); however, the risk of these complications can be reduced with improved glycemic control [2, 3]. In T2D, adherence to medication and lifestyle changes (e.g., weight management, dietary changes) is essential for illness self-management and improving blood glucose control [4, 5].

Self-monitoring is effective for lifestyle change and chronic disease management, and is an important behavioral component of diabetes self-care. For T2D, self-monitoring of weight, calories, and blood glucose can inform and guide other diabetes self-management skills and behaviors through providing in-the-moment feedback that can be linked with other health behaviors [6, 7]. Self-monitoring of weight and dietary changes are key features of effective weight management programs, and more frequent self-weighing is associated with increased weight loss [8–11]. Data from the National Weight Control Registry participants demonstrated that 44 % of successful weight managers weighed themselves daily and 31 % weighed themselves weekly [8, 12]. For diabetes management, self-monitoring of blood glucose (SMBG) is recommended [13]. For T2D patients not prescribed insulin, successful SMBG interventions that have improved glycemic control have included additional support including education, provider feedback, and adequate testing frequency [14, 15].

Barriers to self-monitoring include the amount of time needed to record this information and challenges for patients to interpret the data. Advances in mobile technology can help address these barriers. For example, physical activity can be assessed objectively and monitored in real-time without any effort on the part of the patient. Glucose data can be transmitted to the physician for interpretation; this data sharing between patients and physicians has been shown to have benefit for glycemic control [16, 17]. Finally, mobile applications can display information using graphs and charts that aid with interpretability of data.

Mobile applications that track blood glucose, body weight, and diet and physical activity hold promise for enabling patients to link their behaviors to weight and glucose control, to see patterns in their behaviors over time, and to gain a sense of mastery over their illness. However, despite this potential, there are few data on patients' actual use of these mobile apps. The Pew Research Internet Project survey of 3014 adults in the general population in the USA found that only 2 % used a mobile application specifically for blood glucose or diabetes, though higher percentages reported using apps for weight (12 %), exercise (38 %), and diet tracking (31 %) [18]. As the Pew sample was not diabetes-specific, it is not surprising that only a small percentage reported tracking blood glucose. Recent reviews and meta-analyses have assessed effectiveness of mobile diabetes applications used in trials [19, 20], though this research has focused primarily on mobile phone interventions (e.g., texting-based interventions) rather than use of mobile applications. For example, a meta-analysis of 22 trials found that mobile phone interventions for diabetes management led to significant reductions in HbA1c, and the applications appeared to have greater impact for T2D than type 1 diabetes (T1D) [20]. Other reviews have evaluated whether applications align with clinical standards and have highlighted a disconnect between available applications and evidence-based recommendations [21, 22]. To date, there have been no studies that assess, from a patient perspective, whether and how mobile applications may help with diabetes management.

The specific aim of this study is to survey a clinic population of adults with T2D to determine the frequency of self-monitoring behaviors, and specifically the frequency of mobile application usage for self-monitoring diabetes-related health information.

PATIENTS AND METHODS

We recruited adults (18+ years) with T2D at two endocrinology clinics in the Providence, RI area: a private diabetes/endocrinology group practice, and a hospital-affiliated diabetes/endocrinology clinic. Recruitment took place between January and May of 2015. Patients were recruited by flyers or by being approached by a researcher to participate in a brief waiting room survey. The survey took 5 min to complete and did not collect any identifying data. Completed surveys were placed in a locked box in the waiting room. The Rhode Island Hospital IRB approved all study procedures.

TRACKING DIABETES SURVEY

The brief survey collected demographics and illness-specific information, including year of diagnosis and glycemic control (self-reported HbA1c). Remaining questions focused on health-tracking behavior and mobile phone usage, based upon the Pew Research Internet Project Mobile Health survey [18]. The survey asked about cellphone and smartphone ownership, and whether participants had "apps" on their phone. Participants answered questions about self-monitoring behavior in four diabetes-related areas: weight, diet, exercise, and blood glucose. Participants reported whether they self-monitored and if yes, which method they used (e.g., paper, computer, mobile app), frequency of self-monitoring, and whether they shared their data with anyone (e.g. spouse, healthcare provider). Descriptive statistics and frequencies were calculated. *T* tests and chi-square tests assessed differences between the two clinic samples.

RESULTS

Ninety-six participants completed the survey. Participants were 53 % female and were predominately White (84 %) and non-Hispanic (94 %). See Table 1 for additional participant characteristics. No statistically significant differences in demographic variables or cellphone ownership were observed between participants recruited from the hospital clinic and from the private practice. Therefore, data from the two sites are presented together.

Table 2 presents tracking behaviors across all participants. Blood glucose was the most commonly tracked health information; these data were typically tracked using a glucose meter. Weight, diet, and physical activity were tracked less often, and most commonly using a paper monitoring method. Participants more often reported tracking "regularly" as opposed to "when something came up." Blood glucose data was most commonly shared with someone else (healthcare provider or spouse), while weight, diet, or physical activity information were shared less often.

In our sample, few participants monitored any of these health parameters or behaviors via "apps." Eighty-two percent of respondents owned a cellphone (87 % of participants <50 years old; 82 % of 50 to 64-year olds; 74 % of participants >65). However, only 45 % owned a smartphone (67 % of participants <50 years old; 44 % of 50 to 64-year olds; 29 % of participants >65), and 6 % were unsure if they owned a smartphone (0 % under 50; 8 % of 50 to 64-year olds; 5 % of participants >65). Of smartphone owners ($n = 39$), fewer than half (36 %) had any kind of "app" on their phone; 18 % were unsure. Divided by age group, 40 % of participants under 50 had apps and 7 % were unsure; 13 % of participants 50 to 64 years old had apps and 8 % were unsure; and 7 % of participants over 65 had apps and 7 % were unsure. Among those with apps on their phones ($n = 14$), the most common type of app was for tracking activity (31 %), followed by diet (21 %), weight (13 %), medications (10 %), blood glucose (8 %), sleep (5 %), and blood-pressure (3 %).

DISCUSSION

Mobile health-tracking applications have the potential to increase patient engagement with their own healthcare. Prior research has examined the impact of

Table 1 | Participant characteristics ($n = 96$)

Variable	Hospital clinic ($n = 46$)	Private practice ($n = 50$)	Total	p
Sex (% female)	51 %	56 %	53 %	0.67
Race				0.30
White	84 %	84 %	84 %	
Black	11 %	9 %	10 %	
Asian	0 %	2 %	1 %	
Native American	0 %	7 %	3 %	
Ethnicity				0.63
Hispanic	7 %	5 %	6 %	
Non-Hispanic	93 %	95 %	94 %	
Age (years)	59.2 ± 10.2	62.2 ± 11.7	60.74 ± 11.03	0.36
Years since diagnosis	12.33 ± 10.44	16.32 ± 13.35	14.3 ± 12.05	0.15
HbA1c	7.77 ± 1.54	7.82 ± 2.04	7.8 ± 1.81	0.51
Education				0.35
No diploma	5 %	7 %	6 %	
High school/GED	47 %	44 %	45 %	
College	28 %	38 %	33 %	
Graduate school	10 %	12 %	10 %	
Other	12 %	0 %	6 %	
Employment status				0.89
Not working/retired	44 %	42 %	43 %	
Full time	27 %	31 %	29 %	
Part time	7 %	4 %	6 %	
Disability	18 %	18 %	18 %	
Homemaker	2 %	4 %	3 %	
Other	2 %	0 %	1 %	
Own cellphone?				0.75
Yes	80 %	83 %	82 %	
No	20 %	17 %	18 %	
Own smartphone?				
Yes	50 %	41 %	45 %	0.18
No	41 %	57 %	49 %	
Don't know	9 %	2 %	6 %	

T test and chi-square tests were used to examine differences between clinic groups

mobile phone interventions on health outcomes [19, 20], and the quality of available health-tracking applications for type 2 diabetes [21, 22]. Less is known about the effectiveness of mobile application interventions and how adults with T2D engage with mobile tracking technology in the real world. This study surveyed an adult diabetes clinic population to determine engagement with mobile technology and diabetes-related health behavior tracking.

The majority (82 %) of our sample owned cell phones in 2015, while just under half owned smartphones. These data are lower than the Pew survey findings on technology ownership from 2015, in which 92 % of US adults reported owning cell phones (including smartphones), and 68 % reported owning smartphones (representing an increase from the 2012 Pew findings of 85 % owning cellphones and 53 % owning smartphones) [18, 23]. Although nearly half of participants in this study reported owning a smartphone, few used smartphone apps to track general health or diabetes-related data. This finding is surprising given the multitude of available health applications and diabetes applications in particular.

Adults in the current sample reported using mobile technology most often to track physical activity, which may be due to the availability of physical activity apps that passively track data such as counting steps, as opposed to the user manually entering in information about dietary intake, weight or blood glucose readings. In our survey we found that while many participants track a health behavior, most use a non-technological method such as writing down information or relying on the data stored in blood glucose meters. The finding that they are indeed tracking these behaviors points to the potential role for mobile applications which would offer increased ease of monitoring and benefits of displaying patterns over time.

A recent study conducted by AARP, Inc. in collaboration with Georgia Tech Research Institute, sheds additional light on the use of physical activity trackers (e.g., Fitbit, Jawbone, etc.) in adults over 50. This study provided 92 participants with one of seven activity/sleep trackers to incorporate into their lives for a 6-week trial period. Following the trial, participants reported benefits such as increased motivation,

Table 2 | Self-monitoring activity across health behaviors

	Track? (n = 96)	Method*	Frequency*	How often?*	Share info?*	With whom?*
Weight	Yes: 66 % no: 34 %	Paper: 76 % computer: 6 % app: 9 % other: 9 %	Regularly: 63 % when something comes up: 37 %	1×/day: 23 % 3–5×/week: 9 % 1–2×/week: 30 % 1–2×/month: 26 % <1×/month: 12 %	Yes: 48 % no: 52 %	Provider: 60 % spouse: 51 % family: 26 % Friend: 13 % Other: 8 %
Diet	Yes: 48 % No: 52 %	Paper: 88 % Computer: 6 % App: 6 %	Regularly: 79 % When something comes up: 21 %	>1×/day: 28 % 1×/day: 35 % 3–5×/week: 16 % 1–2×/week: 7 % 1–2×/month: 7 % <1×/month: 7 %	Yes: 47 % No: 53 %	Provider: 63 % Spouse: 45 % Family: 14 % Friend: 7 %
Physical activity	Yes: 21 % no: 79 %	Paper: 53 % computer: 12 % app: 29 % other: 6 %	Regularly: 56 % when something comes up: 44 %	>1×/day: 4 % 1×/day: 23 % 3–5×/week: 27 % 1–2×/week: 12 % 1–2×/month: 19 % <1×/month: 15 %	Yes: 39 % no: 61 %	Provider: 63 % spouse: 63 % family: 27 % friend: 27 % other: 7 %
Blood glucose	Yes: 90 % no: 10 %	Paper: 27 % Meter: 68 % computer: 5 % app: 1 %	Regularly: 86 % when something comes up: 14 %	>1×/day: 47 % 1×/day: 33 % 3–5×/week: 13 % 1–2×/week: 4 % 1–2×/month: 3 % <1×/month: 1 %	Yes: 70 % no: 30 %	Provider: 82 % spouse: 55 % family: 13 % friend: 3 %

*With exception of the "Track?" column, percentages are based on those who endorsed tracking each health behavior

behavior change, and increased awareness of health behaviors [24]. However, participants were skeptical about data accuracy; and requested improved and easily accessible instructions, timely notifications, and additional sensors or trackers for other health information such as blood glucose [24]. These results highlight the value of tracking devices for sustaining health behaviors and the need to improve the ease of starting with and understanding a new technology.

Some trials have demonstrated the effectiveness of mobile interventions to improve glycemic control. In a randomized controlled trial of older adults (≥60 years) with T2D, those who received a "u-health" intervention with individualized instructions on patients' mobile devices achieved better glycemic control compared to SMBG and control groups [17]. In the intervention group, patients' glucose meters were able to transmit data electronically, which then triggered automated but tailored messages sent to the patients' phones. Authors of this intervention have since added physical activity tracking and dietary feedback, and have continued to see positive results with glycemic control, as well as with lipids and decreased body fat [25]. However, a recent meta-analysis of mobile interventions across health areas found small-to-no benefits for glycemic control, weight, and other diabetes-related outcomes in diabetes-specific trials, and found the least benefit in interventions with texting-only medication reminders [26]. These mixed results indicate the need to identify the important components of a mobile health intervention. Providing feedback to patients and integration with current healthcare, along with considerations for theory-based intervention strategies, may be needed to improve outcomes.

A limitation of the current study is its sample size – specifically, the number of smartphone owners and the number who currently use mobile applications to track their health. This finding limits what analyses could be run and what conclusions can be drawn about tracking behaviors of mobile application users within this sample. Our sample was also predominately white and non-Hispanic which limits generalizability of our findings to other groups. More research is needed to examine barriers to utilizing available technologies, and to examine tracking behaviors and relevant health outcomes in a larger population of T2D adults who own smartphones and use mobile applications to track health-related data. While the 2015 Pew survey found that 68 % of adults overall currently own a smartphone, this percentage differed across age groups: 58 % of adults aged 50–64 own smartphones while 30 % of adults 65 and older own smartphones [23]. Further, rates of smartphone ownership increase with income and education level. Therefore, lack of smartphone ownership presents a barrier to accessing and utilizing these available technologies. An additional barrier could be that the multitude of available mobile diabetes apps makes it difficult for patients to select the most appropriate one for them. A 2013 IMS Institute report on commercially available patient apps found over 16,000 healthcare apps, 230 of which were diabetes-specific [27]. Additional guidance from healthcare providers may be needed to navigate this wealth of available apps.

For chronic diseases requiring intensive self-management burden, mobile interventions would ideally integrate with existing healthcare and be evaluated within the larger context of care patients receive. Technology that allows patients with T2D to track their health data and transmit it easily to their healthcare providers could be very beneficial. Technology that integrates blood glucose meters and mobile devices is beginning to become more available, such as glucose meters that sync with a smartphone that then allows data to be uploaded to services such as Apple HealthKit [28]. Automatic syncing of SMBG data with smartphone apps will likely be more appealing to patients as this process will be less burdensome and less error-prone than relying on manual data entry.

Healthcare providers and medical clinics have important roles to play in guiding patients toward integrating mobile applications into their daily lives. This may involve "prescribing" particular apps and training patients to use them. Therefore, physicians and other diabetes providers would need to be informed about available mobile technology to better partner with their patients. App developers also have a key role to play in helping narrow the gap between the availability of numerous health- and diabetes-tracking applications and real-world usage by adults with T2D. Applications that integrate with healthcare delivery are easy to adopt, accept passive entry of data (e.g., transmitted blood glucose values from meter readings), and provide a tailored coaching feature may be more attractive to adults with T2D. Mobile applications for diabetes have an unfulfilled potential to aid patients and providers with increasing engagement with self-management and improving health outcomes.

Compliance with ethical standards

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