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CLINICAL APPLICATIONS

Mobile Phone Technology for Children with Type 1 and Type 2 Diabetes: A Parent Survey

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Abstract

Purpose:

The novel application of information technology has the potential to improve care for children with diabetes. We surveyed parents of children with type 1 diabetes mellitus (T1DM) or type 2 diabetes mellitus (T2DM) to (1) identify their concerns related to their children's diabetes and (2) assess the relationship between these concerns and parental attitudes toward a glucometer integrated into a mobile phone that could provide parents and health care providers with a child's real-time glucose readings via text message and a secure Web site.

Methods:

We conducted a cross-sectional Web-based survey of parents with children ages 10–19 years (125 with T1DM and 77 with T2DM). Parental concerns were grouped by (1) access to their child's provider, (2) parenting challenges, and (3) knowledge about managing their child's diabetes.

Results:

Parental concerns focused mostly on access to their child's health care provider. Over half of respondents expressed interest in subscribing to a mobile-phone-based service. In multivariate logistic regression models, the odds of being willing to use the service increased if parents had concerns about provider access, a child with T2DM, a college education, or currently subscribed to text messaging. Enthusiasm decreased with increasing annual service cost.

Conclusions:

Study participants—particularly parents with provider access concerns or a child with T2DM—were receptive to adopting novel health technology to help manage their children's diabetes. Adoption of such tools is most likely driven by the unmet needs of parents.

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Abbreviations: (OR) odds ratio, (SD) standard deviation, (T1DM) type 1 diabetes mellitus, (T2DM) type 2 diabetes mellitus

Keywords: childhood diabetes, home glucose monitoring, mobile phone, parent concerns

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Introduction

As technology becomes increasingly accessible and affordable, the number of people in the United States adopting new technologies continues to grow. Over 250 million Americans own mobile phones[1] and more than 70% use the Internet.[2] In addition, technology is playing a growing role in the management of chronic diseases. Many clinicians are now investigating the role of the Internet, cellular phones, and other wireless technologies in monitoring their patients and improving access to medical care and information.[3–5] An increasing number of patients are expressing interest in integrating such technologies into their health care management.[6]

Parents of children with diabetes who are in or nearing their adolescent years are a special population who may directly benefit from using technology to help manage their child's illness. The treatment of both type 1 diabetes mellitus (T1DM) and type 2 diabetes mellitus (T2DM) in children is complex. Parents must not only learn about the disease itself, but must also learn to adjust their child's treatment based on signs and symptoms, which can vary from day to day. This may be exceptionally challenging during a child's transition to adolescence when other barriers such as a decrease in child–parent communication and poor adherence to diabetes management may become apparent. Adolescents are avid users of technology,[7] which provides an opportunity for new technologies, such as mobile phones linked to glucometers, to be leveraged to improve communication between patients, their parents, and their health care providers.

The incidence of T1DM and particularly T2DM in children and adolescents is continuing to increase in parallel with the rise of childhood obesity.[8–10] The increased number of affected children places substantial pressure on existing health care systems to deliver effective and timely care. New applications of existing technology may play a transformative role, allowing remote delivery of diabetes care. However, given that parents are essential caregivers for children and adolescents with diabetes, greater insight into parental concerns and receptivity toward implementing new technologic applications is required to ensure that technology can be developed to best address their needs.

In this study, we surveyed parents of children with T1DM and T2DM in order to identify their diabetes-related concerns, identify parental attitudes toward having their child use a mobile phone glucometer prototype, and determine the factors that predict parent willingness to subscribe to the proposed service.

Methods

Research Design

The data for this study were collected from a survey commissioned by the Center for Connected Health and administered by RKM Research Communications, Inc. The survey's primary purpose was to examine current treatment habits of parents of children with diabetes, to explore parental concerns about their child's diabetes care, and to assess parental receptiveness to a combined mobile phone glucometer prototype designed to provide parents with better access to their child's glucose readings. The device would also offer an option to allow parents to provide their child's health care provider(s) with access to this information when deemed necessary. The description of the prototype and its services provided to subjects is reproduced in **Figure 1**.

Sample

Potential subjects were identified by RKM Research and Communications, Inc. using the Authentic Response™ online panel, which includes over 4.1 million consumer panelists from more than 400 Web sites on the Internet. Authentic Response requires that all panelists double opt-in by clicking a link attached in a confirmation email sent after their registration.

Potential subjects were prescreened using the following criteria: subject must be a parent of a child with a diagnosis of diabetes, the child with diabetes must be between the ages of 10 and 19, and the child must be currently receiving treatment for diabetes. Eighteen hundred individuals from the panel who potentially met these criteria were identified and invited by email to participate in the survey (**Figure 2**). Of these, 661 subjects entered the online survey for final screening and data collection. The response rate of 37% compares very favorably to response rates reported by other studies using email to deliver surveys.[11–15] There were no significant differences at this stage in age or gender between respondents and nonrespondents. Survey respondents completed initial screening questions to verify study eligibility. At this stage, 455 ineligible respondents were excluded and 206

Text included in online survey:
The new product is an integrated cell phone and glucometer device given to a child with diabetes. The child will insert a test strip into the product. The phone will display the blood sugar reading immediately, just like any other glucometer. The cost of the strips is similar to other available strips on the market and will be purchased separately by you, the customer.
With the new product, the blood sugar reading will also be transmitted in real time to you, the child's caregiver. You will receive the reading as a text message on your cell phone. The reading will also be transmitted in real time to a secure Web site where you or your child can log on. This Web site contains all your child's readings over time and includes options to see trend data in graphic and text format. The Web site can be accessed at any time and is updated every time a reading is sent from the child's cell phone.
You will have the ability to create a list of people who are able to view your child's data online through a secure Web site, such as your child's physician(s) and other adult caregivers. This feature is optional and controlled by you.

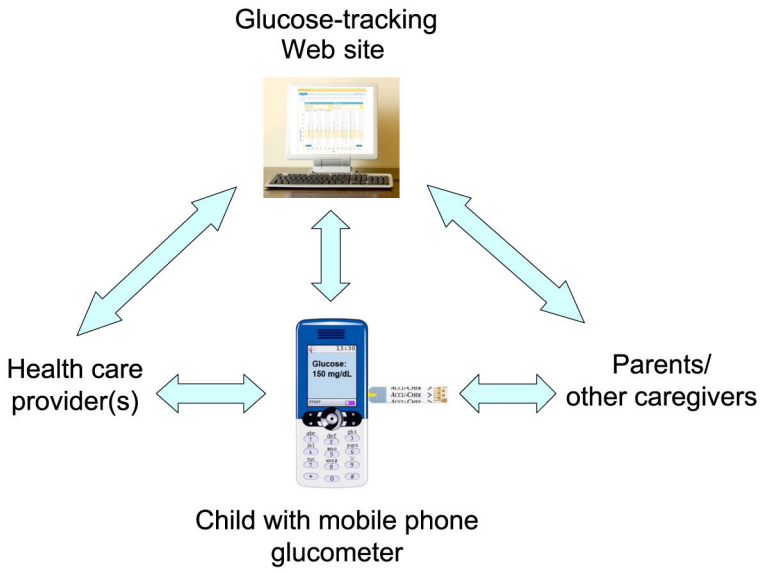

Figure 1. Explanation of mobile phone glucometer and flow of information.

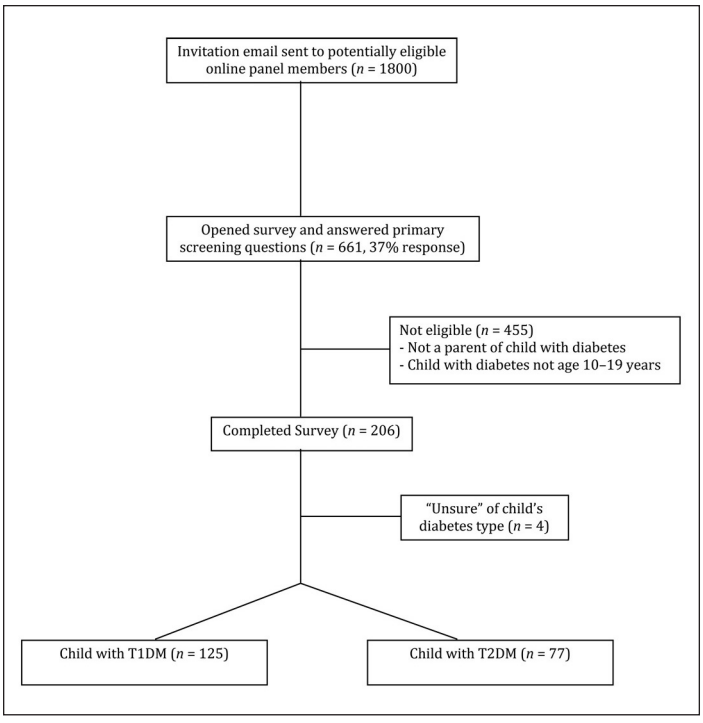

Figure 2. Flow diagram of subject recruitment and participation in survey study.

respondents continued to the main survey. The survey completion rate was 100% (206/206). We subsequently excluded four respondents who were unsure whether their child had T1DM or T2DM.

Survey Development and Administration

A 52-question survey was developed in collaboration with diabetes, technology, and survey specialists. The survey included questions that addressed parent and child demographic information, the child's diabetes treatment habits, parent concerns relating to their child's diabetes, and parent attitudes toward the prototype mobile phone glucometer.

The survey was distributed to potentially eligible online panel members via a link sent by email. Survey invitations included a generic mention of a "health survey," and diabetes was not mentioned so as not to alert potential respondents of the survey topic. Subjects who completed the survey received $5.00. This study was reviewed and approved by the Partners Health care institutional review board.

Measures

Demographic Information

Parent demographic data included age, gender, race, education, yearly income, insurance status, responsibility for child, home Internet access, ownership of a cell phone, and subscription to text messaging. Child demographic data included age, gender, and diabetes type.

Parental Concern

Parental concerns were evaluated by responses to twelve items included in the survey. A team of diabetes and survey specialists worked together to develop twelve statements that reflected different parent concerns relating to their child's diabetes. Subjects were asked to rate statements on a five-point Likert-type scale ranging from 1 (strongly agree) to 5 (strongly disagree). Statements evaluating parent concerns were grouped into three domains: access to child's provider, parenting challenges, and knowledge about managing the child's diabetes. Subject responses were stratified by diabetes type for comparison.

Attitude Toward Prototype Service

In the survey, subjects were presented with a detailed description of a mobile phone glucometer prototype product and asked to rate their initial reaction to the new product. They were then asked to rate how likely they would be to subscribe to the prototype service based on the description provided and on different pricing options, which included an initial setup fee (subjects were randomly presented with $150, $175, or $225) and a monthly charge (subjects were randomly presented with $30, $60, or $90). The charges presented were based on the current costs of cellular phone plans. Three different fees were presented to subjects in order to assess the relative impact of price on consumer enthusiasm. Subjects were asked to rate their initial reaction to the products (1 [very positive] to 5 [very negative]) and their willingness to subscribe to the service (1 [definitely would sign up] to 5 [definitely would not sign up]) on a five-point Likert-type scale.

Statistical Analysis

In univariate analyses, we compared survey responses between parents of children with T1DM versus T2DM using chi-square tests for categorical variables and *t* tests for normally distributed continuous variables. Parental concerns were analyzed as dichotomous variables with "strongly agree" and "somewhat agree" collapsed into one group and "strongly disagree" and "somewhat disagree" collapsed in another group. Subjects responding "unsure" to a parent concern were excluded from that particular analysis. Differences in parental concern domains were also analyzed. We aggregated questions within each domain and designated an overall concern for each domain if parents expressed concerns for at least 4 of 5 items related to access to a child's provider, at least three of four items related to parenting challenges, and at least two of two items related to knowledge about managing their child's diabetes (presented in Results).

We then constructed a logistic regression model to identify independent predictors of subscription willingness for the entire survey sample. Only respondents who reported that they "definitely would sign up" for the service were considered willing subscribers in the analysis. All analyses were performed using SAS software version 9.1 (SAS Institute Inc., Cary, NC).

Results

Survey Respondents

Survey respondents included more parents of children with T1DM (n = 125, 62%) than children with T2DM (n = 77, 38%). **Table 1** presents child and parent demographic characteristics stratified by diabetes type. Children had a mean age of 13.6 ± 2.3 [standard deviation (SD)], with no age difference between diabetes type. Parents of children with T1DM were more likely than parents of children with T2DM to have graduated college (64.0% versus 49.4%, p = .04), more likely have an income of $50,000 or greater (78.5% versus 64.9%, p = .04), and more likely to have employer-provided private insurance (76.8% versus 63.6%, p = .04).

Most respondents reported that they were primarily responsible for their child's diabetes care (57.9%) or shared this responsibility with another person (40.1%). Access and use of technology was high overall, with 96.5% of subjects having home Internet access, 97% of subjects owning cellular phones, and 77% of subjects subscribing to text messaging. There were no significant differences in access and use of technology when comparing parents of children with T1DM and T2DM.

Parental Concerns

Table 2 displays parental concern domains by type of child's diabetes. Overall, parents exhibited most concern with access to their child's provider as illustrated by the top three parent concerns: 84.9% of parents reported that they would like shorter waiting times, 78.7% reported they would like easier phone access to their physician, and 77.8% stated they would like to be able to contact their provider via email to discuss their child's diabetes.

Parents of children with T2DM were significantly more likely than parents of children with T1DM to agree that they would like shorter waiting times to access their child's physician (90.9% versus 80.0%, $p = .04$), that they think their child's physician does not pay as much attention as they should to their diabetes (37.7% versus 23.2%, $p = .03$), that they don't know enough about diabetes to take care of their child in the best way possible

Table 1.
Demographic Characteristics of Parents and Children by Type of Diabetes ($n = 202$)

Characteristics	Total population	T1DM ($n = 125$)	T2DM ($n = 77$)	p value
Child age, years [mean (SD)]	13.6 (2.3)	13.4 (2.2)	13.7 (2.4)	.32
Parent age, %				
Below 45 years	60.4	56.0	67.5	.10
45 years and older	39.6	44.0	32.5	—
Child gender, % male	61.4	58.6	68.8	.09
Parent gender, % male	40.1	37.6	44.2	.36
Parent race, % white	74.3	76.8	70.1	.29
Parent education, % college graduate	58.4	64.0	49.4	.04
Yearly income, % $50,000 and above	73.2	78.5	64.9	.04
Insurance, %				
Private through employer or spouse's employer	71.8	76.8	63.6	.04
Other[a]	28.2	23.2	36.4	—
Parent responsibility for child, %				
Primary responsibility	57.9	54.4	63.6	.17
Share responsibility	40.1	42.4	36.4	—
Child takes care of self	2.0	3.2	0.0	—
Home Internet access, %	96.5	97.6	94.8	.29
Own cell phone, %	97.0	96.8	97.4	.80
Subscribe to text messaging, %	77.0	75.2	80.0	.44

[a] Consolidated Omnibus Budget Reconciliation Act (COBRA) insurance, insurance provided by a former employer, self-purchase of insurance, insurance provided by government programs, and no insurance.

Table 2.
Domain of Parent Concerns by Type of Child's Diabetes[a]

Parent concerns	Total population	T1DM	T2DM	p value
Access to child's provider				
I would like shorter wait times to access my child's physician	84.9%	80.0%	90.9%	.04
I would like easier phone access to my provider to discuss my child's diabetes care	78.7%	76.8%	77.2%	.85
I would like to be able to email my provider to discuss my child's diabetes	77.8%	70.4%	79.2%	.12
More contact with my health care provider would significantly improve my child's diabetes	67.5%	68.0%	61.0%	.31
I think my child's physician does not pay as much attention to my child's diabetes as they should	28.5%	23.2%	37.7%	.03
Overall access concern[b]	53.0%	52.0%	54.5%	.72
Parenting issues				
I feel like I pester my child about glucose readings and meals while at school or away from home	64.8%	64.0%	64.5%	.95
I am concerned my child is not testing glucose readings enough	57.2%	59.2%	54.0%	.47
I am concerned my child is not always telling the truth about their glucose readings	53.5%	55.2%	51.3%	.59
My child is responsible for taking care of him/herself and tells me what I need to know[c]	31.5%	32.0%	30.7%	.84
Overall parenting concern[b]	46.0%	48.8%	41.6%	.32
Knowledge about managing child's diabetes				
I don't know enough about diabetes to take care of my child in the best way possible	22.6%	16.8%	35.1%	.003
The treatment plans given to me by my health care provider are too complex to understand	24.2%	20.8%	32.5%	.06
Overall knowledge concern[b]	15.3%	11.2%	22.1%	.04

[a] Percentage of subjects responding "strongly agree" or "agree."
[b] Percentage of subjects with more than three access concerns, more than two parenting concerns, or more than one knowledge concern.
[c] Percentage of subjects responding "strongly disagree" or "disagree."

(35.1% versus 16.8%, $p = .003$), and that they believe the treatment plans given to them by their health care provider are too complex to understand (32.5% versus 20.8%, $p = .06$).

There were no significant differences in the domains of access to a child's provider and parenting challenges when comparing the concerns of parents of children with T1DM versus T2DM ($p = .72$ and .32, respectively). However, parents of children with T2DM were significantly more likely to have concerns about diabetes management knowledge than parents of children with T1DM (22.1% versus 11.2%, $p = .04$).

Attitudes Toward Adopting the Prototype Mobile Phone Service

Over two-thirds (69.3%) of parents had a "very positive" initial reaction to the proposed mobile phone glucometer prototype service, with 27.7% of parents reporting that they would "definitely sign up" for the prototype service and 27.7% reporting they would "probably sign up." Variables associated with willingness to subscribe to the prototype service on univariate analysis are presented in **Table 3**. The adjusted odds ratios (ORs) for predictors of subscribing to the prototype service were calculated based on these variables. After adjusting for all variables that had been significant on univariate analysis in a logistic regression model, only parent education (adjusted OR 3.17 [1.35–7.42]), having a child with T2DM (adjusted OR 3.38 [1.54–7.46]), parental concerns about access to a child's provider (adjusted OR 4.77, 95% confidence interval [1.85–12.26]), being a subscriber to text messaging (adjusted OR 4.07 [1.22, 13.55]), and yearly cost of the service remained significant predictors of subscribing to the prototype service (adjusted OR 0.99 [0.99–0.99]) (**Table 4**).

Table 3.
Parent Characteristics Associated with Willingness to Subscribe to a Mobile Glucometer Prototype Service

Variables	Parents who would subscribe to service	Parents who would not subscribe to service	*p* value[a]
Parent characteristics, %			
Primarily responsible for child	80.4	49.3	<.0001
Child with T2DM	55.4	31.5	.002
College graduate	75.0	52.1	.003
Nonwhite	35.7	21.9	.04
Parental concerns, %			
Access to child's provider	80.4	42.5	<.0001
Parenting challenges	58.9	41.1	.02
Knowledge about managing child's diabetes	35.1	9.4	<.0001
Technology related			
Subscribes to text messaging, %	92.7	70.9	.001
Yearly cost of service, dollars (SD)[b]	856.52 (±323.39)	987.57 (±286.48)	.006

[a] Calculated using chi-square or *t* tests.
[b] Survey respondents were randomly presented different startup and monthly subscription costs; the "yearly cost of service" represents the calculated average yearly cost presented to each respondent.

Table 4.
Parental Predictors of Subscribing to a Mobile Phone Technology Service[a]

Predictor	Adjusted OR (95% confidence interval)	
Child with T2DM	3.38	(1.54, 7.46)
College graduate	3.17	(1.35, 7.42)
Concerns about access to child's provider	4.77	(1.85, 12.26)
Currently subscribes to text messaging	4.07	(1.22, 13.55)
Increase in yearly cost of service	0.99	(0.99, 0.99)

[a] This model is adjusted for all variables listed in **Table 3**. Responsibility for child, parental race, and concerns about parenting or diabetes knowledge were not significant predictors in the fully adjusted model.

Discussion

In this online survey of parents with children with diabetes, we found a high prevalence of parental concerns about access to their child's health care provider. Moreover, these concerns were strongly associated with parental willingness to adopt mobile-phone-based technology to help monitor and communicate their children's glucometer results. This study provides strong evidence for the link between current problems in our medical system and the willingness for parents to adopt new technologies that can overcome these problems.

Our study also identified significant differences between parents caring for children with T1DM versus T2DM. For example, parents of children with T2DM had significantly more concerns regarding their knowledge about the management of their child's diabetes. This

observed difference may exist for a number of reasons. First, parents of children with T2DM are often of lower socioeconomic status with less education,[16,17] which may present a barrier to understanding the cause of diabetes and how it relates to treatment. Second, T1DM typically presents at an earlier age than T2DM.[16,18] Thus parents of children with T1DM may have had more experience with their child's illness compared to parents of children with T2DM who may be dealing with a relatively new diagnosis. Unfortunately, the duration of the child's diabetes was not a question asked to parents in the study survey. Although we know this data would have been important in understanding parental responses, we believe our main results remain robust despite this missing covariate.

The concern about clinical access found in this online study confirms the results from studies conducted in less technologically adept populations. Ginsburg and colleagues, for example, found that parents of children with diabetes ranked issues relating to access to the diabetes team as a major priority.[19] These concerns reflect the reality that the distribution of pediatricians in the United States does not match the distribution of the pediatric population.[20] Of concern, a study found the number of pediatric endocrinologists is vastly insufficient to address the rising number of children diagnosed with diabetes and obesity in the United States.[21]

Overall, parents were receptive to the idea of using a mobile phone glucometer prototype service. Over two-thirds of parents had a positive initial reaction to the products, and a little over one half of parents expressed interest in signing up for the service. College education was a positive predictor of willingness to subscribe to the prototype service, likely reflecting the positive relationship between education and adoption of technology.[22,23] Extending the potential benefit of new technology for diabetes care into the larger population will require effective approaches to educating parents to become comfortable using these technologies for health-related tasks. Such an undertaking, however, may not be as difficult as it may have been in the past, given the increasing prevalence of cellular phone and Internet use, even in low-income populations. This is reflected in our study, as no significant differences in the utilization of this technology were found between parents of children with T1DM and T2DM.

Parents of children with T2DM were more willing to subscribe to the prototype service. This finding may reflect the unmet needs of such parents brought about by the different experience of raising a child with T2DM versus T1DM. For example, children with T2DM are most often diagnosed during adolescence, which is a time when behaviors are difficult to change. In addition, children with T2DM are often asymptomatic and therefore may be less adherent to treatment compared to children with T1DM.[24] Families of children with T2DM also tend to be of lower socioeconomic status[16,17] and may have less access to care than other populations as a result. All of these issues create barriers for parents to care for their child in the best way possible and may play a role in making them more likely to want to utilize a service as proposed in this study. In addition, because parents of children with T2DM are likely to have diabetes themselves, responses to the survey questions may have also been reflective of personal apprehensions. One study that evaluated the concerns of parents of children with T2DM found that parents often felt pressure to be good role models for their children and voiced their fear of appearing hypocritical when asking their child to carry out activities related to diabetes self-management that they themselves were unable to do.[25]

A study by Gammon and associates provided children (ages 9–15) with cellular phone glucometers that sent text message glucose readings to their parents.[26] Parents in this study reported mixed feelings about the prototype, as some felt such a device would increase the responsibility of parents. The prototype described by Gammon and associates did not provide the child's health care provider with access to their glucose data and may be why parents did not respond as positively as they did in our survey.

Limitations

The results of this study must be considered in the context of the study design. Subjects were selected from an online panel based on selection criteria. Because online panels may interest people who are more likely to utilize technology, recruiting subjects in such a way may have caused selection bias, attracting subjects who may be early adopters of technology. This could have had an effect on how subjects responded to the question of whether they would subscribe to the prototype service, leading to an overestimation of the interest in such an intervention. The selection process in the study may have also led to the lack of ethnic and social diversity in our subject population, as those who utilize technology are more likely to be white and of higher socioeconomic status.[22,23] This is likely the reason why over 70% of the subject population were white and earned greater than the U.S. median household income. Although our study results may not be immediately generalizable

to the overall U.S. population, they do likely represent the attitudes of "early adopters," those individuals who would be most likely to first use newly available technologic tools. Thus the responses described here will be useful for informing the initial implementation of as yet untested tools. Within this selected cohort, parental differences in the attitudes and concerns according to the type of diabetes their child has are valid.

Our survey examined only parents with children between the ages of 10 and 19 years. This criterion was chosen because part of the study survey assessed the possibility of adopting a cellular phone mobile glucometer prototype service, which would require a child who was old enough to use a cellular phone. Because part of the study focused on concerns, excluding parents of children with diabetes who were younger than 10 years of age could have limited the spectrum of concerns exhibited, especially for parents of children with T1DM, who often have children with diabetes who are younger than 10.

Implications

Parent receptivity toward having their child adopt mobile phone technology to enhance their diabetes care has not been extensively studied. This study illustrates that parents of children with diabetes, especially those who are concerned about provider access or have a child with T2DM, are interested in using such technology to help manage their child's illness, indicating that the unmet needs of parents may be drivers of technology adoption. In addition, this study contributes to existing research on the concerns of parents of children with diabetes, especially for those parents of children with T2DM, for whom very little literature exists. It is important that physicians become aware of these parental concerns so that they can work directly with parents to try to address them. Health care providers of children with T2DM must also become aware that the parents of these children may need additional support in helping them to learn more about diabetes and its management.

Further research is needed to explore whether providing children who have diabetes with mobile-phone-based technological tools can provide their parents with additional diabetes management support and help to address their concerns, including poor access to their child's provider. Research is also needed to investigate the reasons why parents of children with T2DM are more likely to know less about their child's diabetes management and whether a technologically based intervention could help provide them with additional diabetes knowledge support.

In conclusion, this study illustrates that parental adoption of technology may be driven by the existence of unmet needs. Parents of children with diabetes, even those who traditionally have less access to technology, are receptive to having their child use mobile phone technology to help with diabetes management, which demonstrates a belief that technology offers a solution. Increased enthusiasm for the use of communications technology in patient care management is helping to overcome traditional barriers to technology adoption, making the integration of such technological tools into clinical practice more feasible.

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