Diabetes Device Use in Adults With Type 1 Diabetes: Barriers to Uptake and Potential Intervention Targets

Molly L. Tanenbaum,[1] Sarah J. Hanes,[1] Kellee M. Miller,[2] Diana Naranjo,[3] Rachel Bensen,[1] and Korey K. Hood[1]

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OBJECTIVE

Diabetes devices (insulin pumps, continuous glucose monitors [CGMs]) are associated with benefits for glycemic control, yet uptake of these devices continues to be low. Some barriers to device uptake may be modifiable through psychosocial intervention, but little is known about which barriers and which patients to target.

RESEARCH DESIGN AND METHODS

We surveyed 1,503 adult T1D Exchange participants (mean age 35.3 [SD 14.8] years, mean diagnosis duration 20.4 [SD 12.5] years) to investigate barriers to device uptake, understand profiles of device users versus nonusers, and explore differences by age and sex. Scales used were the Diabetes Distress Scale, Technology Use Attitudes (General and Diabetes-Specific), and Barriers to Device Use and Reasons for Discontinuing Devices.

RESULTS

Most commonly endorsed modifiable barriers were related to the hassle of wearing devices (47%) and disliking devices on one's body (35%). CGM users (37%) were older than nonusers (mean 38.3 vs. 33.5 years), had diabetes for longer (22.9 vs. 18.8 years), had more positive technology attitudes (22.6–26.0 vs. 21.4–24.8), and reported fewer barriers to using diabetes technology than nonusers (3.3 vs. 4.3). The youngest age-group (18–25 years) had the lowest CGM (26% vs. 40–48%) and insulin pump (64% vs. 69–77%) uptake, highest diabetes distress (2.2 vs. 1.8–2.1), and highest HbA_{1c} levels (8.3% [67 mmol/mol] vs. 7.2–7.4% [55–57 mmol/mol]).

CONCLUSIONS

Efforts to increase device use need to target physical barriers to wearing devices. Because young adults had the lowest device uptake rates, highest distress, and highest HbA_{1c} compared with older age-groups, they should be the focus of future interventions to increase device use.

Medical devices are critical components of the management of type 1 diabetes (T1D). Devices include blood glucose meters, continuous glucose monitors (CGMs), and insulin pumps. These devices are associated with improved glycemic control and reductions in hypoglycemia (1,2). The insulin pump, first invented in the late 1970s (3–5), has seen its number of users climb from <7,000 in 1990 to 100,000 in 2000 (6). Uptake rates in the U.S. now top 60% (7). CGMs first became available two decades after the first insulin pumps (8), and current uptake is much lower. Data from the T1D Exchange (T1DX) indicate that as of 2013–2014, 9% of participants were using CGMs, with the lowest rates in adolescents (4%) and young adults (6%)

[1]Department of Pediatrics, Stanford University School of Medicine, Palo Alto, CA
[2]Jaeb Center for Health Research, Tampa, FL
[3]Department of Psychiatry and Behavioral Sciences, Stanford University School of Medicine, Palo Alto, CA

Corresponding author: Korey K. Hood, kkhood@stanford.edu.

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(9). These rates are disappointing and concerning because of the benefits of CGM on glycemic control as well as health-related quality of life and treatment satisfaction (10–12). Furthermore, because these devices are integral components of automated insulin delivery systems, low uptake of CGMs may negatively affect acceptance and use of automated insulin systems in the future.

Documenting barriers to device use can help in the design of interventions to increase uptake. Consistent with chronic disease management models (13), barriers can be divided into two categories: nonmodifiable and modifiable. Nonmodifiable factors include cost, socioeconomic factors, health insurance, access to health care, and other demographic variables (14–16). Some of these nonmodifiable barriers, such as cost and health insurance, may be best addressed at the policy level. Modifiable factors, however, are addressed at the person or family level. In particular, the "human factors," or patient perceptions, beliefs, attitudes, and preferences, regarding technology use (17) are prime targets for clinical intervention.

Therefore, the overarching goal of this study was to obtain evidence to inform the development of interventions to increase device uptake. Specific aims were to *1*) examine modifiable barriers to device uptake, reasons for discontinuing device use, and factors associated with device use and *2*) describe profiles of device users and nonusers of various age ranges and by sex. To accomplish these aims, an electronic survey was administered to adults with T1D.

RESEARCH DESIGN AND METHODS

Adults with T1D who participate in the T1DX clinic registry and had opted to provide an e-mail address to be contacted about research studies were invited to respond to a Web-based survey. The Stanford University institutional review board approved the study procedures, and all participants provided electronic informed consent before responding. The survey took ~30 min to complete. Participants received a $20 gift card as compensation for their time.

Measures

Diabetes and Demographic Characteristics

Data collected directly from participants included date of birth, current diabetes treatment, and device use. T1DX clinic registry data provided race/ethnicity, sex, and year of diabetes diagnosis.

Barriers to Device Use and Reasons for Discontinuing Devices

A list of 19 possible barriers was created for this study based on literature review and market research results. Participants could select between 0 and 19 barriers. Examples of modifiable barriers were lack of family support to use devices, lack of support from the diabetes care team, and not liking devices on the body. The list also included several nonmodifiable barriers, such as cost of supplies and cost of device (Table 1). Participants not currently using an insulin pump and/or CGM but who had in the past were asked additional questions about when they stopped using their pump/CGM and whether they would consider using a pump/CGM in the future. Participants were also provided with a list of possible reasons for discontinuation and asked to indicate all that applied. For those who discontinued use of insulin pumps, 12 possible reasons for discontinuing were listed, and for CGM discontinuers, 16 possible reasons were listed.

Technology Attitudes: General and Diabetes Specific

Attitudes about technology in general and about diabetes-specific technology were assessed with six and five items, respectively. Each item was rated on a 5-point Likert scale to indicate agreement with the statement. Example items were as follows: "Technology (or diabetes technology) has made my life easier," "Technology (or diabetes technology) has made managing my health easier," and "I am lucky to live in a time with so much (diabetes) technology." Higher scores indicated more positive attitudes about devices and technology. General and diabetes-specific items were summed separately to create two total scores. Internal consistency was 0.93 for general technology attitudes and 0.91 for diabetes-specific technology attitudes.

Diabetes Distress

Diabetes distress was measured with the recently revised 28-item Diabetes Distress Scale for adults with T1D. Participants responded to each item on a 6-point Likert scale. Example items were as follows: "Feeling like I have to hide my diabetes from other people" and "Feeling that I am not as skilled at managing diabetes as I should be." A total score was created by averaging item scores. Cut points were little or no distress (1–1.4), mild distress (1.5–1.9), moderate distress (2.0–2.9), and high distress (>3.0) (18). The internal consistency in this sample was 0.94.

Table 1—Barriers to device use reported by study participants (n = 1,503)

Barrier	% Yes
Nonmodifiable	
Cost of supplies	61.3
Cost of device	57.4
Insurance coverage	57.3
Modifiable	
Hassle of wearing devices all of the time	47.3
Do not like having diabetes devices on my body	34.8
Do not like how diabetes devices look on my body	26
Nervous that the device might not work	20
Do not want to take more time from my day to manage diabetes	17.5
Nervous to rely on technology	17
Worries about what others will think of me	10.5
I do not like diabetes devices because people notice them and ask questions about them	10.4
Too busy to learn how to use a new technology or device	9.2
My diabetes care team has never talked with me about diabetes technology options	4.5
Do not understand what to do with the information or features of the devices	4.5
Not able to get my diabetes care team to write me a prescription	4.4
Not enough support from my family	3.7
Not enough support from my diabetes care team in using devices	2.9
Do not want to have more information about my diabetes	2
My family does not think diabetes devices are important for taking care of my diabetes	0.9

Glycemic Control

Hemoglobin A_{1c} (HbA_{1c}) was obtained from T1DX clinic registry data, which includes all HbA_{1c} values available in the medical chart that is updated annually. Values either came from laboratory collection at the clinic or through point-of-care testing. Values were included in this study if the HbA_{1c} test date was within 3 months of survey completion. HbA_{1c} data were available in 452 of the 1,503 participants in this sample.

Analytic Plan

Descriptive statistics were used to document demographic characteristics and rates of diabetes device uptake. The *t* and χ^2 tests were used to check for differences between participants with and without HbA_{1c} data.

To address aim 1, percentages were calculated to describe endorsed barriers to technology use and reasons for discontinuing device use. Pearson correlations assessed factors that were bivariately associated with endorsing barriers to uptake. Independent-samples *t* tests were used to examine differences between CGM users and nonusers in terms of endorsement of barriers, age, diabetes distress, technology attitudes, and HbA_{1c}.

To address aim 2, the sample was divided into four age-groups and by sex for separate sets of analyses. Percentages of technology uptake were calculated for each age-group. One-way ANOVAs, *t* tests, and χ^2 tests were used to compare the number of reported barriers, reasons for discontinuing CGM and insulin pump use, level of diabetes distress, technology attitudes, and glycemic control among age-groups and between male and female participants. Due to slightly different sample sizes among groups, the Gabriel procedure was used as the post hoc test, whereas the Games-Howell procedure was used when variances were not equal between groups for ANOVAs. Significance tests were at the $\alpha < 0.05$ level. For both aims, the Benjamini-Hochberg procedure was applied to control for the false discovery rate in multiple comparisons (19). All statistical analyses were conducted using SPSS version 23 software (IBM Corporation, Chicago, IL).

RESULTS

Sample Characteristics and Device Uptake Rates

Survey participants were 1,503 adults with T1D. Participant mean age was 35.3 (SD 14.8, range 18–80) years, and mean diabetes duration was 20.4 (SD 12.5, range 3–67) years. The sample was 90% non-Hispanic white, and 61% was female. The breakdown of management regimen was as follows: 38% of participants used insulin pumps only (i.e., no CGMs), 32% used insulin pumps and CGMs, 25% used multiple daily injections (MDIs) only, and 5% used MDIs and CGMs. HbA_{1c} data were available for 452 participants (mean 7.5%, SD 1.34% [58 mmol/mol, SD 15 mmol/mol]). Participants with HbA_{1c} data were older (mean age 40 years, SD 15.4 years) and had a longer diabetes duration (mean 23.4 years, SD 13.3 years) than participants without HbA_{1c} data (mean age 33.3 years, SD 14 years; mean duration 19.8 years, SD 11.9 years; age $t[787] = -7.94$, $P < 0.001$; duration $t[800] = -6.06$, $P < 0.001$). They did not differ on use of CGM or pump.

Aim 1: Barriers and Reasons for Discontinuing Device Use and Factors Associated With Device Use

Participants reported a mean of 3.9 (SD 2.5, range 0–15) barriers to using diabetes devices (Table 1). Most commonly reported barriers were cost related (cost of supplies 61%, cost of device 57%, insurance coverage 57%). Participants also frequently endorsed barriers related to the hassle of wearing devices (47%) and not liking devices on one's body (35%). Infrequently endorsed barriers were lack of support from family (1–4%) and the diabetes care team (3–4%).

We collected data from 249 participants who had discontinued CGM use and 72 who discontinued insulin pump use (Table 2). Nineteen respondents provided data on discontinuing both CGM and pump use. CGM discontinuers reported a mean of 2.85 (SD 2, range 0–11) reasons. Pump discontinuers endorsed a mean of 2.06 (SD 1.64, range 0–7) reasons. For CGM, after cost of supplies (35% endorsed), most commonly endorsed reasons were being bothered by alarms (32%), perceiving the device to be inaccurate (30%), not liking wearing diabetes devices (30%), believing that the CGM took too much time and effort to use (29%), and finding the device painful to wear (28%). For insulin pumps, not liking wearing diabetes devices (46%) and finding them uncomfortable/painful (44%) were the most commonly endorsed reasons followed by cost of supplies (21%) and not trusting the device (21%).

Those who reported more barriers to using devices were younger ($r = -0.18$, $P < 0.001$) and had a shorter duration of diabetes ($r = -0.12$, $P < 0.001$), higher HbA_{1c} ($r = 0.13$, $P = 0.006$), higher levels of diabetes distress ($r = 0.43$, $P < 0.001$), and more negative attitudes about both technology in general ($r = -0.19$, $P < 0.001$) and diabetes-specific technology ($r = -0.21$, $P < 0.001$).

CGM users reported fewer barriers to using diabetes technology than nonusers

Table 2—Top responses to "Why did you stop using your CGM?" and "Why did you stop using your insulin pump?"

Reason for discontinuing	% Yes
CGM (*n* = 249)	
Cost of supplies	35.3
There were too many alarms	32.1
It was not accurate	30.1
Do not like diabetes devices on my body	29.7
Wearing a CGM took too much time and effort	28.9
It was uncomfortable or painful	28.1
Too hard to get it to work right	22.1
Cost of device	21.7
Made it hard for me to sleep	20.1
Did not trust it	18.1
Insulin pump (*n* = 72)	
Do not like diabetes devices on my body	45.8
It was uncomfortable or painful	44.4
Cost of supplies	20.8
Did not trust it	20.8
Too hard to get it to work right	16.7
Cost of device	13.9
Caused other people to ask too many questions about my diabetes	12.5

(Table 3). CGM users were also older than nonusers and had a longer duration of diabetes than nonusers. CGM users had more positive attitudes about technology in general and about diabetes-specific technology than nonusers. There were no significant differences in diabetes distress between CGM users and nonusers. CGM users also had a lower HbA_{1c} than nonusers.

Aim 2a: Device User Profiles by Age

The youngest age-group had the lowest uptake of CGMs and insulin pumps compared with all older age-groups. Table 4 lists all characteristics across age-groups. Percentage of CGM uptake increased with age, whereas the 35- to 50-year-old group had the highest rate of insulin pump uptake. The number of reported barriers to device uptake differed by age-group (F[3, 1,499] = 15.86, $P < 0.001$); the two younger age-groups endorsed more barriers than the two older age-groups. The number of reported reasons for discontinuing CGM use also differed by age-group (F[3, 241] = 6.3, $P < 0.001$); the oldest group endorsed fewer barriers than the youngest and second oldest groups. The number of reasons for discontinuing insulin pump use did not differ significantly by age.

Diabetes distress was higher in the youngest age-group and decreased with age (F[3, 1,499] = 20.67, $P < 0.001$). The two youngest age-groups experienced moderate distress (mean score >2.0), with the 18- to 25-year-old group endorsing higher distress on average. The two older age-groups experienced mild distress (<2.0). General attitudes about technology differed by age (F[3, 1,496] = 3.04, P = 0.03), as did attitudes toward diabetes devices (F[3, 1,460] = 3.03, P = 0.03). The 26- to 34-year-old group had slightly more negative attitudes about general technology than the 35–50-year-old group. Post hoc tests revealed no significant differences in attitudes toward diabetes-specific technology. Finally, HbA_{1c} differed by age (F[3, 448] = 14.42, $P < 0.001$). The youngest age-group had higher HbA_{1c} (mean 8.27%, SD 1.8% [67 mmol/mol, SD 20 mmol/mol) than each of the older groups (26–34 years: mean 7.44%, SD 1.3% [57 mmol, SD 15 mmol/mol]; 35–50 years: mean 7.37%, SD 1.03% [57 mmol, SD 11 mmol/mol]; >50 years: mean 7.17%, SD 1.03% [55 mmol/mol, SD 11 mmol/mol]), which were not significantly different from one another.

For all age-groups, "hassle of wearing devices all the time" was the top modifiable barrier; roughly half of each group endorsed this barrier. The next most common modifiable barrier—"Do not liking having diabetes devices on my body"—was endorsed more frequently by the younger age-groups (39.1–40.2%) than the older age-groups (26.2–29.8%). The same pattern was seen for the next most common modifiable barrier, "Do not like how diabetes devices look on my body." The two younger age-groups also more frequently endorsed being nervous about relying on technology. The youngest age-group was more likely to endorse worrying about what others will think (17.7%) and not wanting others to notice and to ask questions about the device (16.9%) compared with the older age-groups (3.6–9%).

Aim 2b: Device User Profiles by Sex

Table 4 also lists characteristics by sex. Seventy-three percent of women were currently using insulin pumps compared with 65% of men (χ^2[1, N = 1,352] = 9.12, P = 0.003). They were not different in terms of CGM use (χ^2[1, N = 1,352] = 0.12, P = 0.73). Women reported more barriers to device uptake (t[1,350] = −2.87, P = 0.004) and more diabetes distress (t[1,350] = −4.49, $P < 0.001$) than men. Although women had slightly more negative attitudes toward technology than men (t[1,348] = 3.31, P = 0.001), the groups did not differ in terms of attitudes toward diabetes-specific technology. There were no sex differences for age, diabetes duration, or HbA_{1c}.

Women endorsed more barriers than men. Specifically, they endorsed "hassle of wearing devices all the time" more often than men (51% vs. 43%). While women endorsed the barrier "Do not like having diabetes devices on my body" only slightly more often than men (36% and 32%, respectively), more women endorsed the barrier "Do not like how diabetes devices look on my body" than men (30% vs. 20%).

CONCLUSIONS

The survey results indicate that many adults with T1D are using diabetes devices, but most still endorsed barriers to device use, and for some, those barriers led to discontinuation of device use. The intent of this survey was to highlight modifiable barriers that could be addressed through clinical intervention. The most commonly endorsed modifiable barriers were related to the physical experience of wearing devices, including hassle of wearing them, not wanting to wear them, and not liking how devices look on one's body. Given the value of insulin pumps and CGMs for improving glycemic control (7,9,20–22), it is essential to address these physical

Table 3—Differences between CGM users and nonusers

	Users	Nonusers	t	P value	95% CI
Number of barriers reported	3.25 (2.3)	4.32 (2.56)	t(1,301) = 8.33	<0.001[a]	0.81, 1.32
Age	38.29 (14.64)	33.48 (14.55)	t(1,501) = −6.21	<0.001[a]	−6.34, −3.29
Diabetes duration	22.89 (13.09)	18.83 (11.91)	t(1,045) = −5.8	<0.001[a]	−5.4, −2.71
Technology attitudes					
General	26.0 (4.66)	24.84 (4.39)	t(1,498) = −4.86	<0.001[a]	−1.63, −0.69
Diabetes specific	22.61 (3.22)	21.44 (3.46)	t(1,239) = −6.54	<0.001[a]	−1.38, −0.62
Diabetes distress	1.99 (0.76)	2.06 (0.77)	t(1,501) = 1.94	0.052	−0.001, 0.16
HbA_{1c}					
%	7.3 (1.18)	7.67 (1.42)	t(435) = 2.95	0.003[a]	0.11, 0.61
mmol/mol	56 (13)	61 (15)			

Data are mean (SD) unless otherwise indicated. HbA_{1c} n = 452. [a]Test remained significant at the 5% level, with Benjamini-Hochberg adjustment.

Table 4—Device uptake and characteristics by age and sex

	Differences by age					Differences by sex		
Characteristic	18–25 years (*n* = 515)	26–34 years (*n* = 343)	35–50 years (*n* = 366)	>50 years (*n* = 279)	*P* value	Women (*n* = 822)	Men (*n* = 530)	*P* value
Device uptake (%)								
CGM use	26	40	44.5	48		38.7	37.7	0.73
Pump use	64.1	69.4	77.3	68.9		73	65.3	0.003[a]
MDI + glucose meter	32	24.8	17.8	23.7		22.6	28.1	0.02[a]
Other variables								
Number of barriers reported	4.25 (2.64)	4.27 (2.49)	3.72 (2.36)	3.12 (2.30)	<0.001[a]	4.07 (2.6)	3.67 (2.4)	0.004[a]
Number of reasons for discontinuing CGM	3.5 (2.16)	2.76 (2)	3 (2)	1.9 (1.52)	<0.001[a]	3.17 (2.1)	2.38 (1.8)	0.004[a]
Number of reasons for discontinuing pump	2.29 (1.9)	1.91 (1.26)	2 (1.75)	1.89 (1.62)	0.86	1.98 (1.5)	2.28 (1.8)	0.50
Diabetes distress	2.21 (0.86)	2.07 (0.72)	1.95 (0.72)	1.79 (0.61)	<0.001[a]	2.1 (0.8)	1.9 (0.7)	<0.001[a]
Technology attitudes								
General	25.22 (4.12)	24.7 (4.55)	25.65 (4.44)	25.57 (5.22)	0.03[a]	24.86 (4.7)	25.69 (4.2)	0.001[a]
Diabetes specific	21.74 (3.29)	21.55 (3.68)	22.14 (3.17)	22.24 (3.55)	0.03[a]	21.78 (3.5)	22.00 (3.4)	0.24
HbA_{1c}								
%	8.27 (1.8)	7.44 (1.3)	7.37 (1.03)	7.17 (1.03)	<0.001[a]	7.5 (1.3)	7.5 (1.4)	0.89
mmol/mol	67 (20)	57 (15)	57 (11)	55 (11)		58 (15)	58 (16)	

Data are mean (SD) unless otherwise indicated. For reasons for discontinuing CGM, *n* = 64 for 18–25 age-group, *n* = 58 for 26–34 age-group, *n* = 75 for 35–50 age-group, *n* = 48 for >50 age-group, *n* = 149 for women, and *n* = 86 for men. For reasons for discontinuing insulin pump, *n* = 24 for 18–25 age-group, *n* = 21 for 26–34 age-group, *n* = 18 for 35–50 age-group, *n* = 9 for >50 age-group, *n* = 51 for women, and *n* = 18 for men. For HbA_{1c}, *n* = 93 for 18–25 age-group, *n* = 100 for 26–34 age-group, *n* = 139 for 35–50 age-group, *n* = 120 for >50 age-group, *n* = 271 for women, and *n* = 171 for men. [a]Test remained significant at the 5% level, with Benjamini-Hochberg adjustment.

barriers to increase device uptake and improve long-term health outcomes in T1D.

CGM use was higher in this sample (37%) than in the most recently published T1DX data from 2013–2014, where 16% of adult respondents were currently using CGMs (7). As expected, survey respondents who were currently using CGMs reported fewer barriers to using diabetes devices than nonusers. They also had more positive attitudes about technology and diabetes-specific technology than nonusers. Of note, CGM users were older, had a longer duration of diabetes, and had lower HbA_{1c} levels than nonusers. After cost, the most commonly endorsed reasons for CGM discontinuation were device intrusiveness (alarms, taking too much time), concerns about accuracy, and physical discomfort. These reasons are in line with a previous survey of reasons for discontinuing CGMs, which highlighted more specific physical barriers such as discomfort with wearing the device, including issues with insertion, tape, and skin reactions (9).

The majority of participants (70%) used insulin pumps. Among pump discontinuers, which was a smaller group than the CGM discontinuers, the primary reasons for stopping pump use were related to physical issues with wearing the device. These respondents endorsed physical discomfort and simply not liking wearing diabetes devices. In contrast with overall barriers and reasons given for discontinuing CGM use, these non–cost-related reasons were more commonly endorsed than cost-related barriers.

Age was an important factor in device uptake and use. Younger respondents reported more barriers to using devices and more reasons for discontinuing CGMs. The youngest age-group (18- to 25-year-olds) also had the lowest uptake of both CGMs and insulin pumps and the highest levels of diabetes distress and HbA_{1c} compared with the older groups. Younger participants were more likely than older participants to endorse barriers related to not liking wearing diabetes devices, being nervous about relying on technology, and being worried about what others would think or receiving unwanted attention about their diabetes device. These findings highlight the need to address unique barriers to diabetes device use among young adults. Given the substantially lower device uptake rates compared with older cohorts, access to devices and affordability may be primary barriers. However, the current findings point to more personal and social reasons for young adults declining or discontinuing device use, such as not liking how they look on one's body and not wanting to attract attention. As Weissberg-Benchell et al. (23) pointed out, young adulthood is a time of significant transitions, including increased independence, moving away from home, and entering new peer groups. Young adults also face the challenging transition from pediatric to adult medical care, when concerns around loss to follow-up, worsening glycemic control, and increased risk for a range of psychosocial issues, including reproductive health and substance use issues (24–26), are often raised. The introduction of diabetes devices presents an additional transition; little is known about whether or how care transitions influence providers' likelihood of introducing devices.

Sex also plays a role in device uptake. In particular, women had higher pump uptake than men, whereas CGM uptake did not differ. However, despite having higher pump uptake, women also endorsed more barriers to technology use and higher levels of distress than men. The women in the current sample also endorsed the barrier of not liking how devices look on their bodies more frequently than men. This pattern is consistent with previous qualitative findings that women express more

concerns than men about body image and are more self-consciousness specifically relative to wearing insulin pumps (27). More research is needed to understand the reasons why men have lower pump uptake than women despite endorsing fewer barriers to use.

A limitation of this survey is the homogeneity of the sample in terms of race and ethnicity, as participants were 90% non-Hispanic white, and may prevent generalizability of the results to other ethnicities. Respondents had also opted to be contacted for research studies, so the sample was self-selected within the wider network of >20,000 T1DX registry participants. In addition, as has been previously noted, adult T1DX participants receive care at diabetes specialty practices rather than in primary care settings and may be more likely to be insured (7), so the barriers they endorse to device use may not be representative of a population-based sample of adults with T1D. Still, given the possible higher rates of being insured, that the majority of respondents endorsed cost as a barrier to device use is notable. We had a limited number of responses on insulin pump discontinuation, which limited the conclusions we could draw about these participants. Because we did not ask questions about income or insurance coverage, we cannot draw conclusions about reasons for commonly endorsed cost-related barriers. The findings may also not generalize to other countries, which also differ in terms of insurance coverage for devices and uptake rates. For example, a recent audit of device use in the U.K. found that 12% of children and adults with T1D are now using insulin pumps compared with 7% in 2013, but these rates are lower than in the U.S. and other European countries (28). However, the intent of the current survey was to increase our understanding of modifiable barriers to device use to inform future psychosocial intervention designs. Modifying cost-related barriers may require larger-scale policy changes and is therefore beyond the scope of this study's aims.

The findings have implications for guiding the design of interventions to increase uptake of diabetes devices in adults. The results highlight the need for interventions that are tailored to young adults because young adults have the lowest device uptake rates. This group had the shortest diabetes duration compared with the older groups; thus, future research could investigate at what point devices are offered to patients after diagnosis, how devices are introduced (e.g., what education and resources are offered initially), and what ongoing support may be needed to increase comfort with diabetes-specific technology and prevent discontinuation. The foundation of initiating devices is diabetes education and routinely includes instruction on checking blood glucose levels, counting carbohydrates, managing sick days, changing sites, and understanding how insulin works (29,30). Furthermore, clinician and device manufacturer support is essential for device training and education (29). Results from the current study suggest that expectation setting is important, as is a thorough review of potential barriers. Training individuals to problem solve barriers to device use likely would be helpful when they first start because problem-solving skills are associated with optimal health and quality-of-life outcomes (31). Another important element of these investigations will be to incorporate clinicians' perceived barriers to promoting device uptake among their patients. Effective approaches to addressing barriers will address the context of the many transitions that occur during emerging adulthood, including the transition from pediatric to adult care. Furthermore, because young adults had the highest HbA_{1c} levels as well as the highest levels of diabetes distress, interventions that aim to decrease distress while introducing devices and that address barriers may prove more effective. Recent pilot studies of shared medical visits for adolescents with T1D, which have built-in peer support, have shown promise for improving quality of life, adherence, and other psychosocial variables (32,33). Through incorporating peer support with the routine medical visit, this model of care could help to address device-related barriers, particularly the daily burden/hassle and unwanted attention.

Addressing barriers and increasing device uptake will be important for the eventual uptake of automated insulin delivery systems that will involve these device components (34). A recent survey asked respondents about their preferences for successful artificial pancreas technology and found that having small, discreet devices were top priorities followed by effectiveness of the technology and minimal user input (34). When asked what would stop them from using automated insulin technology, respondents listed "size/appearance/constant attachment/potential scarring" second only to cost of the device. Taken together with the current findings, interventions are clearly needed to address physical and social barriers to increase device uptake and decrease discontinuation rates. Although aspects of physical barriers are not inherently modifiable through psychosocial intervention (e.g., device size, discomfort), interventions could target device users' ability to cope with these barriers whether through problem solving, reduction of distress, weighing device and automated insulin delivery system benefits against the daily burden of using them, or other approaches.

In conclusion, many adults with T1D who responded to our survey endorsed modifiable barriers to insulin pump and CGM use that could be prime targets for intervention to increase device uptake. Young adults with T1D, who have the lowest device uptake rates, highest HbA_{1c} levels, and highest levels of diabetes distress, would be particularly good candidates for psychosocial interventions to increase device uptake. Furthermore, the next youngest age-group (26-to 34-year-olds) also had a somewhat lower uptake, endorsed more barriers to device uptake, had higher HbA_{1c} levels, and had more distress than the two older age-groups; psychosocial interventions to increase device uptake could benefit this age-group as well. Given young adults' greater likelihood of endorsing barriers related to not liking wearing devices, approaches to increase uptake will need to target these key concerns. Increasing device uptake and encouraging continued use will be important not only for improving glycemic control in the short term but also for promoting future acceptance of automated insulin technology and improving long-term health outcomes.

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