Type 1 Diabetes in Singapore: Self-Care Challenges, Diabetes Technology Awareness, Current Use, and Satisfaction, an Online Survey

Suresh Rama Chandran[1,2], Cindy Ho[3,4], Ester Yeoh[5,6], Daphne Gardner[1,2]

[1]Department of Endocrinology, Singapore General Hospital, [2]Duke-National University of Singapore (NUS) Medical School, [3]Khoo Teck Puat – National University Children's Medical Institute, National University Health System, [4]Department of Pediatrics, Yong Loo Lin School of Medicine, National University of Singapore, [5]Diabetes Centre, Admiralty Medical Centre, [6]Department of General Medicine, Division of Endocrinology, Khoo Teck Puat Hospital, Singapore

Abstract

Introduction: To describe the self-care challenges, diabetes technology awareness, current use, and satisfaction among adults with type 1 diabetes and parents of children with type 1 diabetes in Singapore. **Methods:** An anonymous online survey was administered between November 2020 and October 2021. Data are presented as mean (standard deviation) or count (percentages). Comparisons between groups were done using the independent samples T-test. **Results:** 251 people (176 adults, 75 parents) participated. The most challenging self-care burdens were carbohydrate counting (24.4%) among adults and insulin dose calculations (28%) among parents. Nocturnal awakenings for diabetes care of their child were a common event (25.3%). Despite high awareness about continuous glucose monitoring devices (77.8% adults, 78.7% parents) the use (24.9% adults, 55% children) remained low. Both adults and parents of children with type 1 diabetes found continuous glucose monitoring to be liberating and less restrictive. Despite overall low insulin pump use (23.9% adults, 29.3% children); satisfaction scores were higher among insulin pump users than insulin pen users ($P = 0.02$). **Conclusion:** Carbohydrate counting and insulin dose calculations were the most challenging self-care tasks among people with type 1 diabetes in Singapore. Diabetes technology use was relatively low in Singapore. Continuous glucose monitoring and Insulin pump users found them to be beneficial.

Keywords: Continuous glucose monitoring, diabetes self-care, insulin pumps, smartphone applications, type 1 diabetes

Introduction

Type 1 diabetes (T1D) is unique among chronic diseases, affecting every aspect of a person's life. T1D self-care involves the relentless repetition of various behaviors and making complex treatment decisions numerous times daily, a tremendous burden for people with T1D.[1] Fortunately, diabetes technology has made considerable progress over the past decade and now offers opportunities to reduce this self-care burden. Diabetes technologies currently support all the major aspects of T1D self-care: glucose monitoring, insulin delivery, and decision-making.[2] The appropriate use of diabetes technologies has improved glycaemia, and quality of life and reduced diabetes-related distress.[3]

However, multiple barriers to diabetes technology uptake exist in Asia. The incidence and prevalence of T1D are low in Asia compared to Western populations,[4,5] contributing to the public's poor awareness of the condition.[6] Further, most countries in Asia do not have reimbursement schemes for diabetes consumables and devices for T1D self-care,[7] requiring the end-user to pay "out-of-pocket". People with T1D wanting to start technology use have limited choices due to the presence of only a few diabetes technology companies in Asia. Only Medtronic and Abbott had a significant presence in Singapore during this study.

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Address for correspondence: Dr. Suresh Rama Chandran, Department of Endocrinology, Singapore General Hospital, Level 3, Academia, 20 College Road, 169856, Singapore.
E-mail: suresh.rama.chandran@singhealth.com.sg

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On the contrary, the uptake of diabetes technology in Europe and the United States is increasing, with reported insulin pump and CGM usage rates of 41.8%–63% and 30%–44.6%, respectively.[8,9] While similar data on technology use from Asia is unavailable, insulin pump use at the adult T1D clinic at a tertiary care hospital, the largest cohort of adults with T1D in Singapore, is 25% (unpublished), with an even lower glucose sensor usage. In March 2020, the Agency of Care Effectiveness in Singapore assessed the benefits of insulin pump therapy. It published a guidance document recommending insulin pumps for T1D, paving the way for insulin pumps to be partially reimbursed for people with T1D who meet certain eligibility criteria.[10] Singapore is unique in sharing the socio-cultural and demographic features with countries of South East Asia while having a per capita GDP comparable to the developed nations.[11] This study aimed to describe the self-care challenges, diabetes technology awareness, current use, and satisfaction of people with T1D in Singapore, data about which is currently lacking.

Materials and Methods

We conducted a one-time anonymous online survey from November 2020 to October 2021. Adult Singapore residents (age ≥ 21 years) or parents of children with T1D were eligible to participate. We advertised the survey on social media platforms and online T1D support groups.[12]

The online survey instrument comprised six major sections (Supplementary Material) Demographics and Diabetes History, Diabetes Self-care, Diabetes Technology, Diabetes Smartphone Application Use, Glucose Monitoring Device Satisfaction Survey for T1D (GMSS-T1D),[13] and Insulin delivery device satisfaction Survey for T1D (IDSS-T1D).[14] GMSS-T1D comprises 15 items, and IDSS-T1D comprises 14 items, both answered on a 5-point Likert scale. GMSS-T1D has four subscales: openness, emotional burden, behavioral burden, and trust. IDSS-T1D has three subscales: effective, burdensome, and inconvenient. A higher score on each subscale indicates a higher degree of the measured attribute. Diabetes self-care behaviors are the repetitive tasks a person with T1D must do daily involving glucose measurement and recording, insulin administration, and decision-making. Diabetes distress among adults with T1D was assessed using the 2-item questionnaire (DDS2).[15] The content of diabetes smartphone application use was developed based on prior published diabetes smartphone app-based surveys.[16] We chose the most downloaded diabetes-related apps available on "App Store" and "Play Store" in Singapore to be listed in the survey, with an additional free text option to document unlisted applications. We administered the survey in English only.

Insulin pumps available in Singapore during the study period were Medtronic Paradigm, Medtronic 640 G and 670 G systems, and the Roche Accu-Chek Spirit Combo Pump. The continuous glucose monitoring (CGM) devices were Abbott Freestyle Libre and Medtronic Guardian 2 and 3 sensors. Apart from the above, products not commercially available in Singapore were purchased overseas and in use among some people with T1D in Singapore.

Unless specified otherwise, descriptive data are presented as mean and standard deviation, mean (SD), or as percentages, *n* (%). Comparisons between groups were done using independent samples student's *t*-test. A two-sided P value ≤ 0.05 was considered statistically significant. IBM SPSS Statistics Ver. 21 was used for all statistical analyses.

Ethical Aspect

The SingHealth Institutional Review Board granted exemption for informed consent for this study (Ref No: 2020/2959), dated 01 November 2020. The exemption was based on the methodology of this study which involved an anonymous survey without personal identifiers. FormSg,[12] a self-service form builder platform, was used to administer the survey and collate responses anonymously. The study was carried out in accordance with the Declaration of Helsinki (2013).

Results

Two hundred fifty-one people, 176 adults living with T1D and 75 parents of children with T1D participated in the survey. Their demographic characteristics are presented in Table 1. 66.5% of the adults and 65.3% of the parents who responded to the survey were women. The majority of the children were in the age group of 11–20 years (64%), with more than half (54.7%) girls. The highest education achieved among the parents compared to the general population of Singapore was skewed toward larger proportions with more advanced education. This suggests a bias in the profile of parents who responded to this survey.[17]

Among children, two-thirds (66.7%) were diagnosed below 10 years of age, while 16.5% of surveyed adults were diagnosed similarly young. The mean duration of diabetes was 17.8 (12.2) years for adults and 6.4 (5.8) years for children. Only 23.3% of adults and 28% of children had a self-reported HbA1c of < 7% (53 mmol/mol). Severe hypoglycemia was prevalent in both groups, with at least one episode in the past year among 51.7% of adults and 41.3% of children. Severe hypoglycemia was described in the survey as low blood glucose leading to loss of consciousness, fits (seizures), or a person requiring help from someone else to treat low blood glucose. Diabetes ketoacidosis (DKA) was rarer among adults, with only 4% of adults experiencing an episode or more in the past year. In comparison, 18.7% of children had at least a DKA episode in the past year. The average DDS2 score among adults was 2.5 (1.1), denoting moderate diabetes distress.

Diabetes self-care

Approximately half (44.3% of adults and 49.4% of parents) of the survey participants reported being confident or very confident with diabetes self-care [Table 2]. The most challenging diabetes self-care action was carbohydrate counting in adults (24.4%), followed by the need to keep

Table 1: Baseline characteristics of survey participants

Characteristic	People living with type 1 diabetes (n=176)	Parents of children with type 1 diabetes (n=75)
Age, years		
21–30	56 (31.8%)	1 (1.3%)
31–40	38 (21.6%)	15 (20%)
41–50	30 (17.0%)	40 (53.3%)
51–60	32 (18.2%)	16 (21.3%)
61–70	18 (10.2%)	3 (4%)
≥71	02 (1.1%)	0 (0%)
Sex		
Female	117 (66.5%)	49 (65.3%)
Male	59 (33.5%)	26 (34.7%)
Child's age, years		
0–5	--	5 (6.7%)
6–10	--	16 (21.3%)
11–15	--	23 (30.7%)
16–20	--	25 (33.3%)
≥21	--	6 (8%)
Child's sex		
Female	--	41 (54.7%)
Male	--	34 (45.3%)
Ethnicity		
Chinese	131 (74.4%)	44 (58.7%)
Malay	8 (4.5%)	1 (1.3%)
Indian	23 (13.1%)	26 (34.7%)
Others	14 (8%)	4 (5.3%)
Highest education		
Primary school	0 (0%)	0 (0%)
Secondary school	16 (9.1%)	4 (5.3%)
Junior college/polytechnic/ diploma	69 (39.2%)	22 (29.3%)
Graduate	62 (35.2%)	24 (32%)
Postgraduate	29 (16.5%)	25 (33.3%)
Age at diagnosis, years		
0–5	9 (5.1%)	26 (34.7%)
6–10	20 (11.4%)	24 (32%)
11–15	44 (25%)	20 (26.7%)
16–20	16 (9.1%)	4 (5.3%)
21–30	41 (23.3%)	1 (1.3%)
≥3	46 (26.1%)	0 (0%)
Diabetes duration, years	17.8 (12.2)	6.4 (5.8%)
HbA1c,%		
≤7% (≤53 mmol/mol)	41 (23.3%)	21 (28%)
7.1–8% (54–64 mmol/mol)	91 (51.7%)	33 (44%)
8.1–9% (65–75 mmol/mol)	30 (17%)	9 (12%)
9.1–10% (76–86 mmol/mol)	9 (5.1%)	7 (9.3%)
10.1–11% (87–97 mmol/mol)	2 (1.1%)	3 (4%)
11.1–12% (98–108 mmol/mol)	2 (1.1%)	1 (1.3%)
≥12.1% (≥109 mmol/mol)	1 (0.6%)	1 (1.3%)

Contd...

Table 1: Contd...

Characteristic	People living with type 1 diabetes (n=176)	Parents of children with type 1 diabetes (n=75)
SH episodes in the past 1 year		
0	85 (48.3%)	44 (58.7%)
1-2	30 (17%)	7 (9.3%)
3-4	30 (17%)	12 (16%)
≥5	31 (17.6%)	12 (16%)
DKA episodes in the past 1 year		
0	169 (96%)	61 (81.3%)
1–2	7 (4%)	14 (18.7%)
Diabetes distress score (DDS2)	2.5 (1.1%)	--

DKA=Diabetes ketoacidosis; SH=Severe hypoglycemia; Diabetes distress score was calculated as the average of the two-item DDS2 questionnaire from DDS17

Table 2: Type 1 diabetes self-care

Characteristic	Person with T1D (n=176)	Parents of children with T1D (n=75)
Confidence in diabetes self-care		
Not confident at all	1 (0.6%)	5 (6.7%)
Somewhat confident	55 (31.3%)	18 (24%)
Neutral	42 (23.9%)	15 (20%)
Confident	69 (39.2%)	32 (42.7%)
Very confident	9 (5.1%)	5 (6.7%)
Most challenging diabetes self-care action		
Frequent finger-prick blood glucose monitoring	33 (18.8%)	11 (14.7%)
Carbohydrate counting	43 (24.4%)	9 (12%)
Multiple daily insulin injections	11 (6.3%)	8 (10.7%)
Insulin dose adjustments based on food and blood glucose	15 (8.5%)	21 (28%)
Insulin dose adjustments for activity/exercise	28 (15.9%)	6 (8%)
Keeping a record of glucose, food, insulin, and activity	38 (21.6%)	15 (20%)
Others	8 (4.5%)	5 (6.7%)
Diabetes self-care experiences*		
Feeling unwell from low blood glucose	54 (30.7%)	16 (21.3%)
Feeling unwell from high blood glucose	49 (27.8%)	7 (9.3%)
Forgetting to measure blood glucose	41 (23.3%)	18 (24%)
Felt unsure about how to calculate insulin dose	45 (25.6%)	17 (22.7%)
Forgetting to take medication or insulin	27 (15.3%)	11 (14.7%)
Not knowing whom to contact when in need of assistance	13 (7.4%)	4 (5.3%)
Not knowing how to identify high or low blood glucose	11 (6.3%)	8 (10.7%)
Been left without medication/supplies	6 (3.4%)	5 (6.7%)
None of the above	58 (33%)	26 (34.7%)
Frequency of nocturnal awakenings to manage diabetes		
1–2 times per week	154 (87.5%)	50 (66.7%)
3–4 times per week	14 (8%)	6 (8%)
Every night	8 (4.5%)	19 (25.3%)
Keeps ketone test strips		
None	135 (76.7%)	23 (30.7%)
Blood ketone test strips	33 (18.8%)	48 (64%)
Urine ketone test strips	6 (3.4%)	2 (2.7%)
Both	2 (1.1%)	2 (2.7%)
First point of contact for assistance with diabetes self-care		
Diabetes nurse educator	59 (33.5%)	43 (57.3%)
Diabetes specialist doctor	64 (36.4%)	19 (25.3%)
Internet	34 (19.3%)	7 (9.3%)
Primary care provider	14 (8%)	1 (1.3%)
Support groups	4 (2.3%)	5 (6.7%)
Smartphone applications	1 (0.6%)	0 (0%)

* Multiple responses per participant are allowed; the proportions will not add up to 100%

a diabetes diary (21.6%). Among parents, insulin dose adjustment for food and blood glucose was the most challenging self-care task (28%). 87.5% of adults and 66.7% of parents woke up at night 1–2 times per week or more to manage diabetes. A fourth (25.3%) of the parents woke up every night to manage their child's diabetes. Data about other diabetes self-care aspects are presented in Table 2.

Diabetes smartphone application use

Despite ubiquitous smartphone ownership among adults and parents, only about half or less (54.5% of adults and 40% of parents) had ever used a diabetes smartphone-based application (App) [Table 3]. The most used apps among adults were "mySugr," "Diabetes: M," and "My Fitness Pal." Among parents, the most used apps were "mySugr," "Nutritionist Buddy Diabetes," "My Fitness Pal," and "Libre." Most of the participants did not report problems with Diabetes App usage. The most useful features of the diabetes app were the blood glucose diary and the bolus calculator for both adults and parents. Among diabetes app users, about half used the App daily, with the majority (83.3% adults and 86.7% parents) reporting only minor or no technical problems. Most of the users (82.3% adults and 86.7% parents) also felt the diabetes apps were somewhat, very, or extremely useful.

Diabetes technology: Awareness and current use

Awareness of CGM devices was relatively high (>75%). In comparison, awareness of partial reimbursements for insulin pumps (<50%), smartphone applications that can help with insulin bolus dose calculations, and closed-loop insulin pump devices were low (both <25%). Table 3. The primary glucose monitoring device was a capillary glucose meter in 76% of the adults, while among children, a CGM device use was the primary device in 55%. Freestyle Libre was the most used CGM device (19.3% in adults, 37.3% in children). Insulin pen devices (disposable or refillable) were the most common insulin delivery device (69.9% in adults and 65.4% in children). 23.9% of adults and 29.3% of children used an insulin pump for insulin delivery. Medtronic Paradigm was the most used insulin pump. Sensor augmented pump, Medtronic 640 G system was in use among 14.3% of adults and 13.6% of children. Only two adults (4.8%) and three children (13.6%) reported using the Medtronic 670 G closed-loop system [Table 4]. Medtronic 780 G system was not available in Singapore at the time of this survey.

Device use satisfaction

The total scores for glucose monitoring satisfaction were similar among adults and parents (3.4 (0.6) vs. 3.4 (0.5)). Comparisons of sub-scores between capillary glucose meter vs. freestyle libre users showed a higher score for openness in the libre group and a lower score for trust in the libre group, consistent across both adults and parents.[Table 5]. WH Polonsky *et al*.[13] described "Openness" as a sense of liberation or perceived reduction in feeling restricted due to the use of a glucose monitor and "Trust" as the perceived reliability of the monitor and the sense of confidence that the results were accurate.

Insulin delivery device satisfaction total score was 3.5 (0.5) among adults and 3.3 (0.6) among parents. When disposable pen use was compared with insulin pumps, the total score as well as the "effective" subscore were higher among the insulin pump group in both adults and parents [Table 5]. In addition, the inconvenient sub-score was significantly higher for disposable pens among adults. The effective sub-score highlights the perception that the device is valuable and useful. In contrast, the inconvenient sub-score relates to the specific hassles and discomfort of using the device while trying to live one's life.[18]

Discussion

This study describes the self-care challenges and technology awareness, usage, and satisfaction among adults and parents of children with T1D in Singapore.

Carbohydrate counting in adults and insulin dose adjustments for parents was the most challenging self-care action. Sleep disruptions due to nocturnal awakenings were common. Despite the availability and awareness of diabetes management smartphone applications, only half use them daily. Flash glucose monitoring (FGM) devices were perceived to be less restrictive than capillary glucose monitors; however, the degree of trust in the FGM devices was lower. Both adults and parents found insulin pumps to be more effective insulin delivery devices than disposable pens.

Diabetes smartphone applications are designed to help with self-care challenges like carbohydrate counting, insulin dose calculations, and record keeping. However, many barriers prevented their continued use. Carbohydrate counting is a challenge faced by most people with T1D. An adult Singaporean's average daily carbohydrate intake is 337.4 grams, with up to 60 grams of refined sugar.[19,20] In Singapore, it is also common for people to dine at local food courts, with up to 3/4th eating at least one meal a day at local food courts.[21] These food courts often do not display nutritional information, and the recipe and portion for the same item could vary from place to place. Singapore General Hospital has been conducting the dose adjustment for normal eating (DAFNE) course for adults with T1D for the past 11 years. Participants are taught advanced carbohydrate counting in the DAFNE course. However, even DAFNE graduates have reported challenges in carbohydrate counting due to a lack of information about Asian cuisines and hidden carbohydrates in some recipes. Most smartphone applications for carbohydrate counting have limited information on Asian cuisine. Nutritionist Buddy Diabetes[22] provides information on Asian cuisines, including the Singapore Energy and Nutrient Composition[23] published by Health Promotion Board Singapore and the Malaysian Food Composition[24] and the USDA food database. However, as the recipes and serving sizes are not standardized, they can vary across different vendors within Singapore. Hence translating this information into a meal can be challenging and error-prone, even with the availability of such smartphone applications.

Digital diabetes diaries record essential information like carbohydrates, insulin dose, and activity in addition to blood glucose readings, unlike most capillary glucose monitors,

Table 3: Smartphone diabetes application (App) use

Characteristics	Adults with type 1 diabetes	Parents of children with type 1 diabetes
Smartphone ownership	*N*=176	*N*=75
Yes	174 (98.9%)	75 (100%)
iPhone	91 (51.7%)	46 (61.3%)
Android	83 (47.2%)	29 (38.7%)
Diabetes app use ever	96 (54.5%)	30 (40%)
Type of diabetes app used (ever users)	*N*=96	*N*=30
mySugr	31 (17.6%)	6 (8%)
Glucose Buddy	3 (1.7%)	4 (5.3%)
Beat Diabetes	0 (0%)	1 (1.3%)
Blood Sugar Tracker	3 (1.7%)	3 (4%)
Nutritionist Buddy Diabetes	6 (3.4%)	6 (8%)
Diabetes M	27 (15.3%)	3 (4%)
One drop diabetes Management	1 (0.6%)	2 (2.7%)
Blood sugar log	3 (1.7%)	2 (2.7%)
Carb manager: Keto diet App	0 (0%)	1 (1.3%)
Glucose Blood Sugar Tracker	5 (2.8%)	1 (1.3%)
Contour Diabetes App	5 (2.8%)	1 (1.3%)
My Fitness Pal	26 (14.8%)	6 (8%)
Libre	11 (6.3%)	6 (8%)
Others*	12 (6.8%)	5 (6.7%)
Problems encountered during diabetes app use (ever users)	*N*=96	*N*=30
Software crashes	7 (4%)	2 (2.7%)
Inconsistent results	15 (8.5%)	5 (6.7%)
Units of measurement issues	6 (3.4%)	2 (2.7%)
Difficulty understanding advice	5 (2.8%)	0 (0%)
Results not aligning with medical advice	7 (4.0%)	1 (1.3%)
None	52 (29.5%)	19 (25.3%)
Others[†]	15 (8.5%)	2 (2.7%)
Useful features in a diabetes app (all participants)	*N*=176	*N*=75
Contact details and diabetes information	45 (25.6%)	24 (32%)
Blood glucose diary	132 (75%)	54 (72%)
Blood glucose check reminders	51 (29%)	32 (42.7%)
Meal and carbohydrate diary	97 (55.1%)	46 (61.3%)
Bolus calculator	101 (57.4%)	47 (62.7%)
Blood glucose targets	56 (31.8%)	29 (38.7%)
Appointment calendar	56 (31.8%)	30 (40%)
Diabetes care team details	51 (29%)	27 (36%)
Dietary advice	55 (31.3%)	18 (24%)
Others[‡]	13 (7.4%)	5 (6.7%)
Diabetes app usage frequency (ever users)	*n*=96	*n*=30
Never	12 (12.5%)	6 (20%)
Once a month or less	18 (18.8%)	2 (6.7%)
Once a week or less	10 (10.4%)	1 (3.3%)
A few days in a week	6 (6.3%)	5 (16.7%)
Daily	22 (22.9%)	9 (30%)
Every time I eat or take insulin	28 (29.2%)	7 (23.3%)
Diabetes app usefulness (ever users)	*n*=96	*n*=30
Not at all useful	1 (1%)	2 (6.7%)
Not very useful	16 (16.7%)	2 (6.7%)
Somewhat useful	50 (52.1%)	14 (46.7%)
Very useful	22 (22.9%)	7 (23.3%)
Extremely useful	7 (7.3%)	5 (16.7%)
Diabetes app function status (ever app users only)	*n*=96	*n*=30
Does not function	1 (1%)	2 (6.7%)

Contd...

Table 3: Contd...

Characteristics	Adults with type 1 diabetes	Parents of children with type 1 diabetes
Some functions work, but slow or has technical problems	7 (7.3%)	0 (0%)
App works overall, but slow or has technical problems at times	8 (8.3%)	2 (6.7%)
Mostly functional with minor problems	56 (58.3%)	21 (70%)
Perfect with no technical problems	25 (25%)	5 (16.7%)
Diabetes App: Ease of use (all participants)	*n*=176	*n*=75
There are no/limited instructions, confusing	10 (5.7%)	8 (10.7%)
Useable after a lot of time/effort	10 (5.7%)	8 (10.7%)
Useable after some time/effort	47 (26.7%)	16 (21.3%)
Easy to learn to use with given instructions	63 (35.8%)	24 (32%)
Able to use immediately, simple	46 (26.1%)	19 (25.3%)

*Other diabetes apps mentioned: Adults: Carbs and Cals (1), Dafne Online (3), Glimp (1), Insulin (1), Jade (1), Samsung (2), SmartLog (2), Xdrip (1); Parents: Dexcom (1), Loop (1), Xdrip (1), Tomato (1), TruMatrix (1)

†Other App problems: Adults: connection issues with BG meter/CGM (6), taking too much time (5), too tedious to use, or time-consuming (4). Parents: Pressure (1)

‡Other useful features of diabetes app mentioned: Adults: Carbohydrate information for local foods (4), 24/7 chat support (1), food labels, insulin carbohydrate ratio advice (1), alarms linked to CGM (2), prospective BG prediction (1), record physical activities (2), own notes entry (1), all in one app (1); Parents: connect to CGM real-time (1), Bluetooth connectivity (1), app to scan CGM (1), exercise advise (1), allow photo of meals (1)

Table 4: Diabetes technology: Awareness and current use

Item	Person with T1D (*n*=176)	Parents of children T1D (*n*=75)
Technology awareness*		
Continuous glucose monitoring sensors	137 (77.8%)	59 (78.7%)
Digital diabetes diary applications	122 (69.3%)	40 (53.3%)
Glucose meters with wireless data logging	106 (60.2%)	44 (58.7%)
Government insulin pump Subsidy	79 (44.9%)	32 (42.7%)
Applications for carbohydrate counting	83 (47.2%)	34 (45.3%)
Applications for bolus calculations	40 (22.7%)	14 (18.7%)
Closed-loop insulin pumps	37 (21%)	17 (22.7%)
Current technology use		
Primary glucose monitoring device		
Capillary glucose meter	134 (76.1%)	36 (48%)
Freestyle libre	34 (19.3%)	28 (37.3%)
Medtronic CGM	6 (3.4%)	6 (8%)
Dexcom CGM	1 (0.6%)	4 (5.3%)
DIY glucose monitoring systems	0 (0%)	1 (1.3%)
Others	1 (0.6%)	0 (0%)
Insulin delivery device		
Disposable insulin pens	91 (51.7%)	23 (30.7%)
Insulin pumps	42 (23.9%)	22 (29.3%)
Refillable insulin pens with cartridges	32 (18.2%)	26 (34.7%)
Insulin vials and syringes	10 (5.7%)	3 (4%)
DIY insulin delivery solutions	1 (0.6%)	1 (1.3%)
Current insulin pump	**(n=42)**	**(n=22)**
Medtronic paradigm	26 (61.9%)	7 (31.8%)
Medtronic 640 G pump with sensor	6 (14.3%)	3 (13.6%)
Medtronic 640 G pump without sensor	7 (16.7%)	4 (18.2%)
Medtronic 670 G system	2 (4.8%)	3 (13.6%)
Roche Accu chek spirit combo pump	1 (0.6%)	5 (22.7%)

CGM=Continuous glucose monitoring; DIY=Do-it-Yourself (A glucose sensor linked to non-FDA approved devices for glucose data transmission to smartphone or smartwatch); DIY system in use for glucose monitoring was "Libre with Miaomiao" and for insulin delivery was "Loop for iOS."

*Multiple responses are allowed; proportions will not add up to 100%

which only store blood glucose. Digital diabetes diaries which can wirelessly connect to selected devices are currently available in Singapore (e.g. "mySugr," "Diabetes: M"). Such a device may reduce the burden of keeping a manual BG

Table 5: Satisfaction of current technology use

Glucose monitoring satisfaction survey (GMSS-T1D)								
	People with type 1 diabetes				Parents of children with type 1 diabetes			
	All (n=176)	Capillary glucose meter (n=134)	Freestyle libre (n=34)	*P*	All (n=75)	Capillary glucose meter (n=36)	Freestyle libre (n=28)	*P*
Total score	3.4 (0.6)	3.4 (0.5)	3.4 (0.6)	0.55	3.4 (0.5)	3.3 (0.4)	3.5 (0.6)	0.36
Openness	3.3 (0.7)	3.1 (0.7)	3.6 (0.8)	<0.01	3.5 (0.6)	3.2 (0.4)	3.8 (0.7)	<0.01
Emotional burden	2.7 (0.7)	2.7 (0.7)	2.7 (0.8)	0.77	2.6 (0.7)	2.7 (0.5)	2.7 (0.9)	0.98
Behavioral burden	2.4 (0.8)	2.5 (0.8)	2.3 (0.7)	0.14	2.7 (0.8)	2.8 (0.9)	2.7 (0.7)	0.57
Trust	3.5 (0.8)	3.7 (0.8)	3.1 (0.8)	<0.001	3.5 (0.7)	3.7 (0.5)	3.4 (0.7)	0.09
Insulin delivery satisfaction survey (IDSS-T1D)								
	People with type 1 diabetes				Parents of children with type 1 diabetes			
	All (n=176)	Disposable insulin pens (n=91)	Insulin pumps (n=42)	*P*	All (n=75)	Disposable insulin pens (n=23)	Insulin pumps (n=22)	*P*
Total score	3.5 (0.5)	3.4 (0.5)	3.6 (0.4)	0.02	3.3 (0.6)	3.2 (0.6)	3.5 (0.4)	0.02
Effective	3.7 (0.6)	3.6 (0.5)	4.0 (0.4)	<0.001	3.7 (0.6)	3.4 (0.5)	4.1 (0.4)	<0.001
Burdensome	2.6 (0.6)	2.5 (0.5)	2.7 (0.5)	0.29	2.9 (0.6)	3.0 (0.7)	2.9 (0.5)	0.83
Inconvenient	2.8 (0.8)	2.8 (0.7)	2.5 (0.7)	<0.01	3.0 (0.8)	3.0 (0.8)	2.8 (0.6)	0.23

diary as the BG readings and time sync automatically. The user can enter carbohydrate information and other notes. However, wireless integration between diabetes apps and glucose meters, and glucose sensors is limited to a few devices necessitating manual information entry for others. This can become tiresome eventually, and many people stop using the apps. Data visualizations in these applications make clinical decisions data supported. However, previous research into the impact of digital smartphone applications on type 1 diabetes outcomes is mixed. Some studies showed an improvement in HbA1c among those with a higher starting HbA1c (>8% or > 64 mmol/mol).[25] In contrast, most showed no impact on HbA1c despite significantly impacting self-efficacy and psychological outcomes.[26,27] "mySugr" app usage improved HbA1c and glucose variability in highly engaged users (>5 logs per day).[28] However, such apps cannot keep the users engaged consistently for long, and many people find it cumbersome and stop using the app after a while.[29] Digital Health or mHealth applications on a smartphone have tremendous potential due to the ubiquitous availability of smartphones. However, current applications cannot keep the user engaged in the long term. Further, concerns about the need for regulation, quality control, data privacy, and technological issues like inter-operability remain to be fully addressed.[30]

Despite the high awareness about its availability, adults' CGM use in Singapore remained low. However, the usage in children was comparable to Europe and USA type 1 diabetes databases. Interestingly, a similar online survey of people with T1D in Europe had an 84% usage rate for insulin pumps or glucose sensors,[31] much higher than that reported from clinic databases.[8,9] Participant bias in online surveys to those with technology access and higher socioeconomic status is likely to overestimate the technology use. The lower CGM uptake among adult Singapore residents is likely primarily driven by the lack of a reimbursement system in Singapore. Parents, however, perceive a higher risk of managing type 1 diabetes in a young child without a CGM. They cannot rely on a young child to alert them about hypoglycemia and are more likely to pay for a CGM to access real-time or on-demand data. Data on the cost-effectiveness of CGM devices for T1D is accumulating[32,33] and it is encouraging to see more governments moving toward reimbursement for CGM devices for people with T1D.[34]

Users of Freestyle Libre, both adults and parents, felt it more liberating and less restrictive than capillary glucose meter users, similar to findings from other studies.[35] The lower trust score for Freestyle Libre compared to capillary glucose meters supports the authors' observations of people with T1D reporting confusion and distress due to significant discrepancies between readings in a flash monitoring system and the capillary glucose meter. Studies have also found that the flash glucose monitoring system tends to have a negative bias and shows lower sensor readings than capillary glucose readings.[36,37] Overall, the satisfaction score for FGM use was not significantly higher than for SMBG. In addition, the out-of-pocket payment system might have also resulted in lower FGM use despite the high awareness. Continued improvements in CGM accuracy and availability of more real-time CGM devices, as opposed to flash systems, might change this in the future.

Satisfaction scores for the insulin delivery device were significantly higher in insulin pump users than disposable pen users, despite the majority using only the basic insulin pump. Only 4.8% of adults and 13.6% of children used a closed-loop system. However, less than a quarter of the adults and children in Singapore used an Insulin pump, much lower than the nearly half to three-quarters who use an Insulin pump in Europe and the USA.[8,9,31]

Fear of nocturnal hypoglycemia places a tremendous burden on parents of young children with frequent night-time awakenings.[38] The unpredictability of activity and dietary intake makes T1D care in a young child extraordinarily challenging and stressful for parents. Technology use, especially sensor-augmented pump therapy, has significantly reduced nocturnal hypoglycemia.[39] However, the expectation that this would translate to reduced fear of hypoglycemia and nocturnal awakenings among parents may not be borne out, as some reports suggest persistent worry and anxiety despite technology use.[38]

This study is the first to survey people living with T1D and parents of children with T1D in Singapore. Findings from this study could be cautiously extrapolated to people with T1D living in other Asian countries due to the similarities between the out-of-pocket payment system and the challenges of carbohydrate counting in Asian cuisine. Limitations of our study include that we used the survey in only English and that it was an online survey. Hence the participants may not fully represent the entire T1D population in Singapore. This bias could have resulted in an overestimation of the technology usage rates. The parental diabetes distress scale was designed for only parents of children aged 11–21 years. However, we have applied it to parents of all children with T1D in this survey.

Conclusion

Carbohydrate counting and insulin dose calculations were the most challenging self-care actions for people and parents of children with T1D in Singapore. Despite high awareness about the availability of smartphone applications, and CGM, the usage remained low due to many barriers. CGM users, both adults and parents of children with T1D, found it liberating and less restrictive. Insulin pump users had greater satisfaction with device use than disposable insulin pen users.

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Authors' contribution

Suresh Rama Chandran was involved in the conception, literature search, data acquisition and analysis, manuscript preparation, editing and review. Cindy Ho, Ester Yeoh and Daphne Gardner were involved in data acquisition, analysis, manuscript editing and manuscript review. All authors take responsibility for the integrity of the work as a whole from inception to published article and are guarantors for this work.

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Conflicts of interest

There are no conflicts of interest.

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