Bridging the Gap in Carbohydrate Counting with A Mobile Application: A Needs Assessment survey.

Asmaa Housni, Alexandra Katz, Lucien Junior Bergeron, Alain Simard, Ashley Finkel, Amélie Roy-Fleming, Meranda Michel Nakhla, Anne-Sophie Brazeau

Submitted to: Journal of Medical Internet Research
on: June 17, 2024

Table of Contents

Bridging the Gap in Carbohydrate Counting with A Mobile Application: A Needs Assessment survey.

Asmaa Housni[1] BSc; Alexandra Katz[1, 2] BSc; Lucien Junior Bergeron[3] PhD; Alain Simard[4]; Ashley Finkel[1] BSc; Amélie Roy-Fleming[1] MSc; Meranda Michel Nakhla[5] MSc; Anne-Sophie Brazeau[1] PhD

[1]School of Human Nutrition McGill University Montreal CA
[2]Faculté de médecine Université de Montréal Montreal CA
[3]Faculté de Médecine et des Sciences de la Santé Université de Sherbrooke Sherbrooke CA
[4]Petit Cactus inc. Sherbrooke CA
[5]Research Institute of the McGill University Health Center Division of Endocrinology Montreal Children's Hospital Montreal CA

Corresponding Author:
Anne-Sophie Brazeau PhD
School of Human Nutrition
McGill University
21111 Lakeshore road
Sainte-Anne-de-Bellevue
Montreal
CA

Abstract

Background: Carbohydrate counting (CC) can be burdensome and difficulty with adherence have been reported. Automated CC through mobile applications offers innovative solutions to ease this burden.

Objective: A cross-sectional online survey was conducted to identify 1) perceived barriers to CC by Canadians living with type 1 diabetes (T1D), and 2) app-features that would help reduce these barriers. As a secondary objective, apps being used by participants were compared with the suggested app-features.

Methods: Participants completed a 39-closed- and open-ended question online survey to identify barriers in CC, preferred CC app-features, and current CC app use. Respondents rated the importance of barriers and proposed app-features using a 5-point Likert scale.

Results: Participants (n=196: 74% women, mean age 40±17 years, mean diabetes duration 22±14 years, 91% relied on CC to determine insulin doses at mealtimes) reported carbohydrate identification barriers, nutrient interaction and insulin dose calculation barriers, as well as psychosocial barriers. App-feature preferences emphasized the need for features for nutrient analysis (84%), personalization of the app (77%), insulin bolus calculation (74%), and support from healthcare professionals (69%). The rated features were cross-referenced in each app reported being used by participants (n=16 different apps). Most apps allowed nutrient analysis. However, none offered personalization, one app calculated bolus dose, and only one app provided support from healthcare professionals.

Conclusions: Currently used CC mobile apps do not meet the needs of people with T1D. A novel CC app with app-features such as photo recognition, reliable nutrient values and personalized bolus calculations could reduce CC burden.

(JMIR Preprints 17/06/2024:63278)
DOI: https://doi.org/10.2196/preprints.63278

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✔ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**

Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v

Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

Title: Bridging the Gap in Carbohydrate Counting with A Mobile Application: A Needs Assessment survey.

Authors : Asmaa Housni[1], Alexandra Katz[1] [2], Lucien Junior Bergeron[3], Alain Simard[4], Ashley Finkel[1], Amélie Roy-Fleming[1], Meranda M. Nakhla[3], Anne-Sophie Brazeau[1]

Affiliations:

[1] School of Human Nutrition, McGill University, Montréal, Canada

[2] Faculté de médecine, Université de Montréal, Montréal, Canada

[3] Faculté de Médecine et des Sciences de la Santé, Université de Sherbrooke, Sherbrooke, Canada

[4] Petit Cactus inc., Canada

[5] Research Institute of the McGill University Health Center, Division of Endocrinology, Montreal Children's Hospital, Montréal, Canada

Author Contributions: A.H.: Conceptualization, methodology, project administration and survey consolidation, protocol - original draft, protocol - review & editing, participant recruitment, formal analysis, visualization, writing - original draft, writing - review & editing. **A.K.:** Participated in analysis, writing - original draft, writing - review & editing. **L.J.B.:** Participated in analysis, writing - review & editing. **A.S.:** Participated in analysis, writing - review & editing. **A.F.:** Participated in analysis, writing - review & editing. **A.R.F.:** project administration and survey consolidation, writing - review & editing. **M.N.:** writing - review & editing. **AS.B.:** Conceptualization, survey consolidation, protocol - review & editing, writing - review & editing, supervision. AS.B. is the principal investigator and guarantor of this work and, as such, has full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Corresponding author:

Anne-Sophie Brazeau, RD, PhD

Associate professor

School of Human Nutrition, McGill University

21,111 Lakeshore drive, Montréal

Canada, H9V 1X9

514-398-7848

anne-sophie.brazeau@mcgill.ca

Running title: Carbohydrate counting app needs assessment survey

Key Message: Current carbohydrate counting mobile apps fall short in meeting the needs of people with type 1 diabetes. App-features like photo recognition paired with nutrient values derived from validated databases, personalized bolus calculations, and tracking factors affecting blood glucose

levels are perceived to facilitate carb counting and alleviate the cognitive burden.

Keywords: Type 1 diabetes, carbohydrate counting, mobile application

Word count

Abstract: 251, Body of manuscript: 3151

Table: 2, Figures: 3, Appendices: 2

Abstract

Background: Carbohydrate counting (CC) can be burdensome and difficulty with adherence have been reported. Automated CC through mobile applications offers innovative solutions to ease this burden. A cross-sectional online survey was conducted to identify 1) perceived barriers to CC by Canadians living with type 1 diabetes (T1D), and 2) app-features that would help reduce these barriers. As a secondary objective, apps being used by participants were compared with the suggested app-features.

Methods: Participants completed a 39-closed- and open-ended question online survey to identify barriers in CC, preferred CC app-features, and current CC app use. Respondents rated the importance of barriers and proposed app-features using a 5-point Likert scale.

Results: Participants (n=196: 74% women, mean age 40±17 years, mean diabetes duration 22±14 years, 91% relied on CC to determine insulin doses at mealtimes) reported carbohydrate identification barriers, nutrient interaction and insulin dose calculation barriers, as well as psychosocial barriers. App-feature preferences emphasized the need for features for nutrient analysis (84%), personalization of the app (77%), insulin bolus calculation (74%), and support from healthcare professionals (69%). The rated features were cross-referenced in each app reported being used by participants (n=16 different apps). Most apps allowed nutrient analysis. However, none offered personalization, one app calculated bolus dose, and only one app provided support from healthcare professionals.

Conclusion: Currently used CC mobile apps do not meet the needs of people with T1D. A novel CC app with app-features such as photo recognition, reliable nutrient values and personalized bolus calculations could reduce CC burden.

1. Introduction

People living with type 1 diabetes (T1D) (~300,000 in Canada) need to administer subcutaneous insulin to maintain stable blood glucose levels and prevent long-term complications.[1, 2] Instead of a fixed bolus insulin regimen tied to predetermined meal plans, carbohydrate counting (CC) offers dietary flexibility by empowering individuals to tailor their mealtime insulin based on the carbohydrate content of their meals.[3] However, adherence to CC can be burdensome and difficult.[4]

CC requires frequent BG monitoring, keeping food records, reading food nutrition labels, and weighing food portions. Additionally, calculations are time-consuming and prone to errors as they involve multiple factors such as the insulin sensitivity factor, insulin-to-carbohydrate ratio, and BG target.[5, 6] Accurate CC is important because greater precision in carbohydrate counting improves insulin dosing accuracy and glycemic control, leading to lower glycated hemoglobin levels.[7] Further, greater differences in carbohydrate estimates are associated with higher glycemic variability.[8] This is significant considering that frequent or large glucose fluctuations may independently contribute to diabetes-related complications.[9]

Automated CC through health technology introduces novel care solutions that can simplify CC for individuals living with T1D. The efficacy of smartphone or tablet applications (henceforth “apps”) in improving self-management among adults with diabetes is well-established.[10-12] In fact, the use of automated carbohydrate estimation compared to conventional methods (i.e., manual calculations) led to improved accuracy in CC, reduced time spent in hyperglycemia, and improved BG variability.[13, 14] However, the use of such apps is limited beyond research settings.[15, 16] According to a survey, young participants lack awareness and have skepticism about the effectiveness of diabetes management apps, which have been shown to be reasons for not using them.[16]

This highlights the necessity of involving people with T1D in the design process to create a more effective and user-centered app design that meets their needs. This is particularly important for adolescents, considering the unique psychological and social challenges they face.[17] Consequently, they may struggle to maintain motivation for self-care behaviours such as CC, as competing priorities often take precedence over the numerous demands of T1D management.[18] This challenge is compounded by the increased glycemic levels disproportionately observed from adolescence through young adulthood (approximately 14 to 24 years).[19] Recognizing the vulnerability of this developmental stage, during which adolescents and young adults must develop new skills and competencies, it is essential to include adolescents in developments of new resources to gain insights into their specific needs.[20]

To understand how a CC app can facilitate CC at mealtimes for people with T1D, the objectives of our study are to identify 1) the perceived barriers to CC and 2) the app-features that would help reduce these barriers. The secondary objective is to compare apps being used by participants with the suggested app-features to identify gaps for a novel CC app that aligns with user preferences and needs. We hypothesized that the needs of people with T1D regarding CC are not met with traditional manual tools nor with the currently used apps.

2. Methods

2.1. Participants

Upon obtaining ethics approval from McGill Research Ethics Board (#22-08-054-02) a national cross-sectional online survey was launched across Canada. Recruitment took place from November 2022 to November 2023 and used a non-probability convenience sample. We sent an announcement through the newsletter to participants of the BETTER Canadian registry of people living with T1D (3800+ participants)[21], and through Canadian diabetes organizations and social media. People with a T1D diagnosis, aged ≥14 years, and living in Canada, were eligible to complete a 30-closed and 9-open-ended question survey. Adolescent and adult participants provided consent before accessing the survey. Parents who completed the questionnaire on behalf of their child with T1D were excluded as the aim was to gather insights and perceptions directly from individuals living with T1D. A final sample of 196 eligible respondents provided consent and completed all the questions of the survey.

Questionnaire and Data Collection

All data was self-reported. The survey was developed and adapted by T1D researchers, certified diabetes educators, and healthcare professionals (HCP) on the team, and subsequently tested by 3 patient-partners to ensure clear understanding of the questions. Questions related to barriers in CC were based on a literature review and proposed app-features were based on the scientific literature as well as a manual search/testing of OS and Android diabetes management applications. A list of identified barriers and proposed app-features was compiled, and consensus was reached among researchers (AH, ASB) for final items included in the survey. The survey was created, in both English and French, on Limesurvey hosted on McGill secure servers (LimeSurvey GmbH, Hamburg, Germany). The final questionnaire contained 13 demographic and diabetes management-related questions, 19 CC needs assessment questions, and 7 questions on patient-provider communication (Appendix A). Respondents rated suggested barriers and app-features on a 5-point Likert scale. The percentage of agreement was calculated based on the frequency of ratings that were either a 4 i.e., “agree” or a 5 i.e., “strongly agree”.

Statistical Analyses

Variables are reported as frequencies, median with interquartile range (IQR), or mean ± standard deviation was computed where indicated for scale variables. Open-ended questions were analyzed by two independent researchers (AH and AK) using an inductive thematic analysis. Individually, each

researcher created a codebook, and then each code was discussed until agreement (100%) was achieved.

3. Results

A total of 196 eligible respondents completed the survey. The majority identified as women (n=145, 74.0%), Caucasian (184, 93.9%), and born in Canada (176, 89.8%). The median [IQR] age was 38 [24-54] years with just over a quarter of participants being youth aged 14-24 years (52, 26.5%). Over half of the respondents (110, 56.1%) use an insulin pump to administer insulin and almost all participants (191, 97.4%) use continuous glucose monitoring systems. Most respondents (178, 90.8%) use CC to determine mealtime bolus insulin and more than half (133, 67.9%) find it difficult managing BG levels around mealtime with CC. Although the majority (147, 75.0%) believe apps could ease CC burden, only n=57 (29.1%) use apps to help with CC, and less than half of them (27 out of 57 using apps, 47.4%) are satisfied with the used apps. (Table 1)

Table 1: Participant (n=196) characteristics

	n (%); median [IQR]
Demographics	
Age, years	38 [24-54]
Youth; 14-24 years	52 (26.5%)
Adults; ≥ 25 years	144 (73.5%)
Gender[a], Women	145 (74.0%)
Born in Canada	176 (89.8%)
Ethnicity	
White/Caucasian	184 (83.9%)
Asian	4 (2.0%)
Arab	3 (1.5%)
Latin American	2 (1.0%)
Black (African, Afro-American, Caribbean)	1 (0.5%)
Other (Iberian, Mixed)	2 (1.0%)
Currently studying	47 (24%)
Highest level of Education acquired	
Highschool level	40 (20.4%)
Cegep, Vocational or Community College	58 (29.6%)
University level[b]	98 (50%)
Medical History and diabetes management	

Diabetes Duration[c], years	**19 [12-32]**
Had at least one diabetes-related consultations in the last year with:	
Medical specialist (Endocrinologist, Pediatrician, Internist)	185 (94.4%)
Family doctor/General practitioner	97 (49.5%)
Registered Dietitian/Nutritionist	69 (35.3%)
Registered Nurse	64 (32.6%)
Other (Psychologist, Dentist, Ophthalmologist)	50 (25.5%)
Use Continuous Glucose Monitoring systems in the last 12 months	**191 (97.4%)**
Use insulin pens or syringes exclusively	**86 (43.9%)**
Use an insulin pump	**110 (56.1%)**
Use of pump features in the last week	
Use an integrated bolus wizard/calculator function	99 (90.0 %) [d]
Use an automated insulin pump	63 (57.3 %) [d]
Use a temporary basal rate	56 (50.9 %) [d]
Use the interruption or suspension of insulin infusion	51 (46.4%) [d]
Use a temporary sensory glucose target (e.g., sleep or sport mode)	47 (42.7%) [d]
Use extended/divided insulin bolus infusion: dual wave/extended bolus	33 (30.0%) [d]
Use the programming of basal rates and changes in basal settings	44 (22.4%) [d]
Other (looping)	1 (0.5%)
Carbohydrate counting (CC) and app users	
Use CC to determine mealtime bolus insulin	178 (90.8%)
Use CC at every meal and snack	145 (81.5%) [e]
Find it difficult managing BG levels around mealtime with CC	133 (67.9%)
Believe apps could ease CC burden	147 (75.0%)
Use an app to help with CC	57 (29.1%)
Satisfied with used apps	27 (47.4%) [f]

[a] n=1 identifies as genderfluid, n=49 as men, n=1 missing; [b] University certificate, bachelor's degree, master's, PhD, MD; [c] n=2 missing; [d] proportion among the 110 pump users; [e] Proportion among the 178 users that use CC to determine mealtime bolus insulin; [f] Proportion among the 57 users that use an app to help with CC. CC: carbohydrate counting. BG: Blood Glucose.

3.1. Barriers to CC

In terms of the barriers to CC that were suggested, identifying the amount of carbohydrates to be consumed was the most agreed upon barrier whether it was in foods without labels (70.4%; i.e., rated scores of 4 or 5), in restaurants or when eating out (74.0%), or when unsure about appetite (74.4%) (Figure 1). This was also reflected in participants' answers to the open-ended questions where quantifying portions was reported as a barrier for CC when eating homemade food or unknown

ingredients, but also for food with labels where the serving size on nutrition labels was unclear or difficult to estimate. Conversely, counting CC in the presence of others or social stigma achieved higher rates of disagreement (57.6%; i.e., rated scores of 1 or 2). However, qualitative data analysis revealed a distinct perspective. Specifically, stigma manifested as feelings of blame and judgment. Participants expressed a fear of alienation, apprehension about receiving, as well as receiving, judgment when eating sugary foods. It also included perceptions of stigma stemming from preoccupation with others' opinions, including HCP, and the fear of “ruining a good day.”

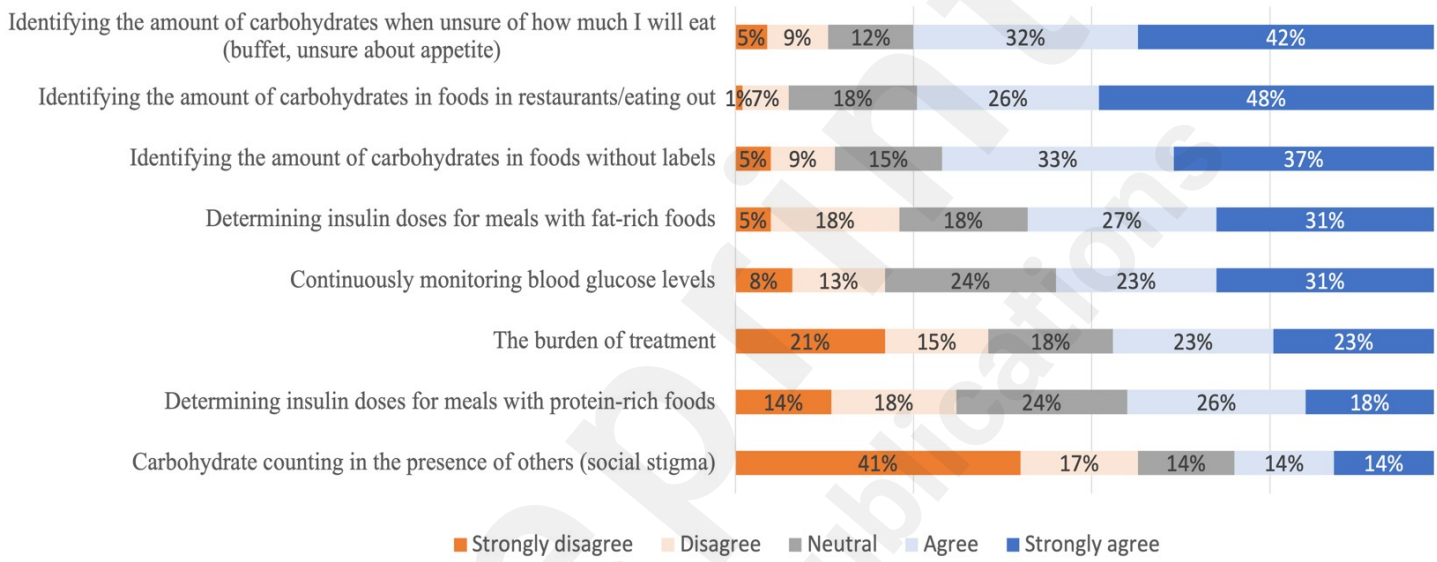


Figure 1: Stacked bar chart of participants’ proportion of agreement with suggested barriers to carbohydrate counting.

3.2. App-features to reduce CC burden

Suggested app-features with the most agreement were the option to view the food nutrition label (167, 85.2%) and the quantification of meal composition (165, 84.2%). Participants expanded upon this in the open-ended responses by suggesting visual cues, comparison pictures to estimate quantities, or shifting towards selection of small-medium-large portions rather than exact grams to reduce the burden. Beyond estimating quantity, emphasis was also placed on reliable nutrient value by suggesting the inclusion of the source of nutrient information and a breakdown of the carbohydrate estimations. On the other hand, gamification features such as earning points or trophies achieved the most disagreement among respondents (75, 38.3%) (Table 2).

Table 2: Agreement Rates for Suggested App Features and Factors Reducing CC Burden

	Rate of agreement, n (%)

uggested app-feature	1 (Strongly disagree)	2 (Disagree)	3 (Neutral)	4 (Agree)	5 (Strongly agree)
Features that would be beneficial to include in a carbohydrate counting app					
amification (earning points/trophies)	50 (25.5%)	25 (12.8%)	42 (21.4%)	40 (20.4%)	39 (19.9%)
-app community building	17 (8.7%)	31 (15.8%)	55 (28.1%)	40 (20.4%)	53 (27.0%)
leal logs into a food journal	11 (5.6%)	15 (7.7%)	41 (20.9%)	53 (27.0%)	76 (38.8%)
upport from healthcare providers	13 (6.6%)	13 (6.6%)	35 (17.9%)	63 (32.1%)	72 (36.7%)
uggestion of insulin bolus doses	11 (5.6%)	10 (5.1%)	30 (15.3%)	46 (23.5%)	99 (50.5%)
ersonalization of the app	9 (4.6%)	7 (3.6%)	29 (14.8%)	47 (24.0%)	104 (53.1%)
uantification of meal composition	5 (2.6%)	7 (3.6%)	19 (9.7%)	60 (30.6%)	105 (53.6%)
iewing the food nutrition label	5 (2.6%)	4 (2.0%)	20 (10.2%)	47 (24.0%)	120 (61.2%)
Features that would facilitate food journaling					
eminders for forgotten logs	27 (13.8%)	37 (18.9%)	49 (25.0%)	49 (25.0%)	34 (17.3%)
hoto recognition	6 (3.1%)	10 (5.1%)	24 (12.2%)	39 (19.9%)	117 (59.7%)
ave meals in a *Favorite* section	5 (2.6%)	4 (2.0%)	19 (9.7%)	53 (27.0%)	115 (58.7%)
ccess recent meal items.	3 (1.5%)	4 (2.0%)	29 (14.8%)	62 (31.6%)	98 (50.0%)
ombine food items into recipes	4 (2.0%)	5 (2.6%)	28 (14.3%)	56 (28.6%)	103 (52.6%)
rack BG levels and related meals/insulin	3 (1.5%)	10 (5.1%)	31 (15.8%)	52 (26.5%)	100 (51.0%)
clude meal notes and post-adjustments	4 (2.0%)	8 (4.1%)	37 (18.9%)	63 (32.1%)	84 (42.9%)
og factors influencing BG	4 (2.0%)	4 (2.0%)	22 (11.2%)	64 (32.7%)	102 (52.0%)
Factors to increase my trust in a carbohydrate counting app					
alidated with clinical trials	3 (1.5%)	10 (5.1%)	37 (18.9%)	57 (29.1%)	89 (45.4%)
ecure data storage	5 (2.6%)	12 (6.1%)	49 (25.0%)	41 (20.9%)	89 (45.4%)
nformation on safety mechanisms	5 (2.6%)	12 (6.1%)	32 (16.3%)	63 (32.1%)	84 (42.9%)
ccess formulas used for calculations	11 (5.6%)	12 (6.1%)	44 (22.4%)	47 (24.0%)	82 (41.8%)
ualifications of app developers	9 (4.6%)	13 (6.6%)	46 (23.5%)	47 (24.0%)	81 (41.3%)
ealth Canada’s approval	8 (4.1%)	11 (5.6%)	39 (19.9%)	50 (25.5%)	88 (44.9%)
ndorsed by the healthcare team	10 (5.1%)	8 (4.1%)	43 (21.9%)	52 (26.5%)	83 (42.3%)

3.3. App-features to streamline meal logging and maintaining a food journal

A majority of respondents concurred on integrating a 'Favorites' section (168, 85.7%), enabling users to store frequently consumed food items for convenient access. Additionally, a significant majority (166, 84.7%) expressed agreement with the inclusion of options to log factors influencing glycemia such as alcohol intake, physical activity, and medications. In the open-ended responses, participants noted many other factors affecting BG levels that they deemed important to record, including stress, sick days, menstrual cycle, sleep, time and site of injections, as well as other medical factors (menopause, gastroparesis). Less than half of the participants (83, 42.3%) agreed that reminders for forgotten meal logs would improve the ease of maintaining meal records. (Table 2)

3.4. Factors to increase trust in a CC app

To understand factors contributing to increased app usage, participants indicated their level of agreement with various elements that would increase their trust in CC apps. The factor with the

highest agreement levels was the inclusion of information regarding safety mechanisms integrated into the app to prevent accidental overdosing of insulin/hypoglycemia (i.e., transparency regarding the source of suggestions) (147, 75.0%). This was closely followed by endorsement from validated results in clinical trials (146, 74.5%). The qualifications of the app developers received the least agreement, although still important for most participants (128, 65.3%) (Table 2). Additionally, open-ended answers highlighted participants' emphasis on users' feedback, consistency in results obtained from the app, and improved glycemic management outcomes.

3.5. App-features comparison with current apps

Suggested app-features were cross-referenced in each app (n=16) reported to be used by participants. It was found that, while most apps allow meal composition quantification, less than half display nutrition labels. Only one app calculated bolus dose, one app provided support from healthcare professionals, and none offered personalization for diabetes characteristics (Figure 2).

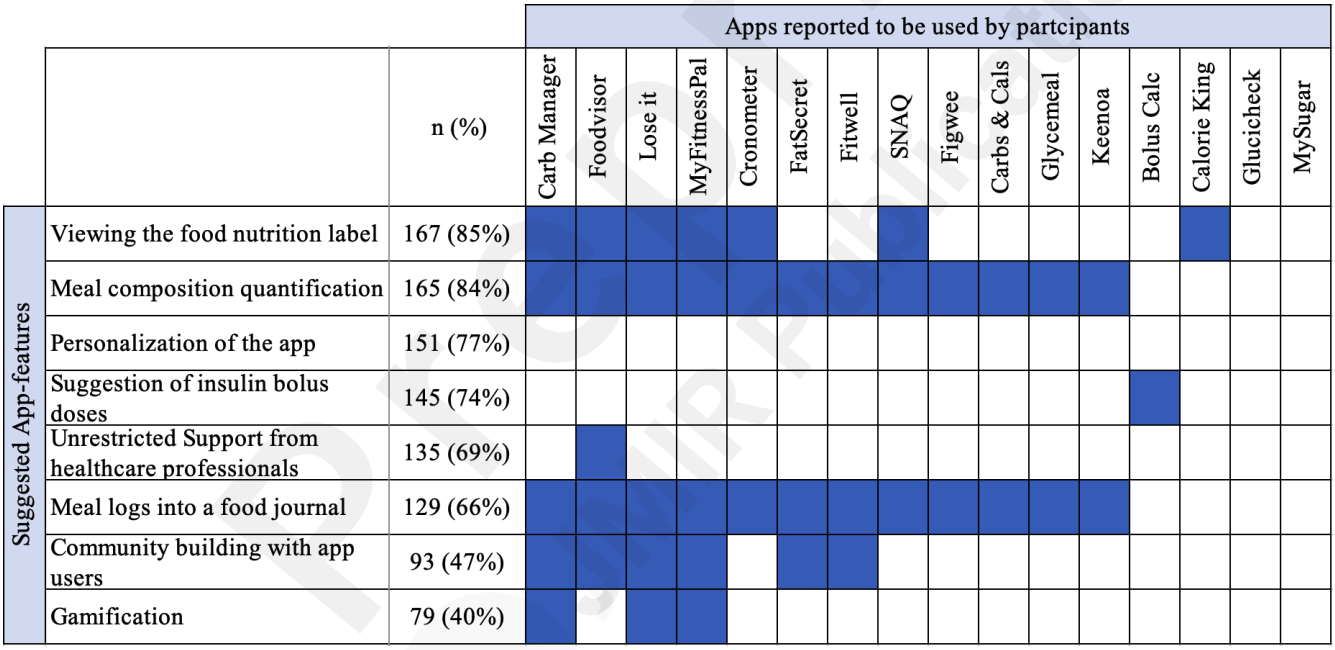


Figure 2: Suggested app-features were ranked by rate of agreement (4 or 5 on the Likert scale), then cross-referenced in each app (n=16) reported to be used by participants; blue box = app provides the feature.

3.6. Qualitative analysis of open-ended questions

All the open-ended answers were analyzed following inductive qualitative thematic analysis and revealed 22 themes categorized as barriers in CC and app features aimed at mitigating these barriers (Figure 3). While some themes were suggested to participants as survey options, participants introduced several new barriers and app features. Sources of errors was an emergent theme to

describe both calculation mistakes, but also external factors such as unreliable nutrient values from available food databases as well as nutrition labels (Appendix B – Theme description). Another barrier mentioned was the fear of developing eating disorders stemming from hyper-fixation on food, feeling pressured to eat or restrict intake, and adhering to a rigid meal schedule rather than having spontaneous meals. The use of technology was suggested as a means to reduce this hyper-fixation by concealing calorie information. The limited use of CC apps also emerged as a barrier to CC, mainly due to their lack of reliability and lack of satisfaction by participants as main drawbacks. Another drawback limiting the use of these apps is the diverse range of needs from the app; Participants reported both dissatisfaction with the lack of comprehensiveness in CC apps, as well as a desire for an app designed for occasional, partial use, catering to users who may not require it frequently but find it beneficial when encountering new food items. Moreover, the general perceived benefit from CC was limited as participants reported no utility of CC on explaining BG trends, and no impact of CC on improving BG. Finally, limited support from HCP was also a barrier suggested by participants. The limited time during appointments, the narrow focus on glycated hemoglobin rather than overall health, the limited knowledge in nutrition of their medical specialist, and the lack of understanding of patient perspective were all factors in this reduced perception of HCP support. Other strategies brought forward as alternatives to avoid CC were categorized as barriers to CC. Participants mentioned avoiding carbohydrates altogether, using CGM to correct BG, eating the same thing, “guesstimating", or using trial and error (Figure 3).

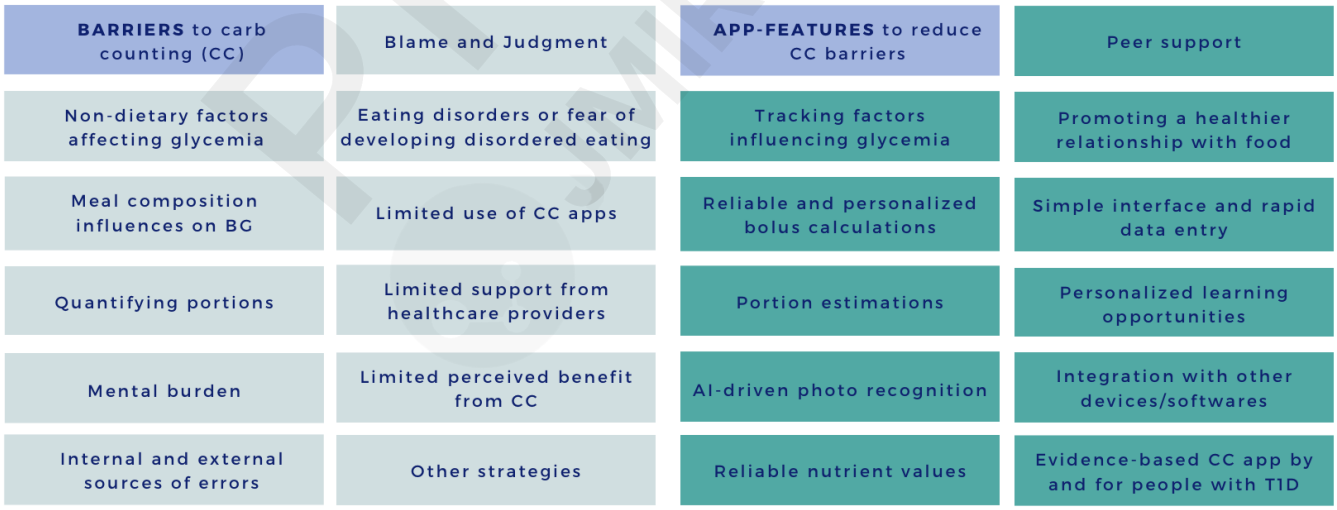


Figure 3: Emerging themes of reported barriers to carbohydrate counting and app-features perceived to reduce these barriers, derived from the qualitative analysis.

4. Discussion

Participants reported carbohydrate identification barriers, nutrient interaction and insulin dose calculation barriers, as well as psychosocial barriers. Existing CC apps, used by people with T1D, fall short in meeting their preferred app-features. Similarly, Martinez et al. found that of 80 existing apps for people with T1D, none met the criteria of an “ideal” app [22], suggesting a significant gap between what users want and what is available. App-features for general T1D management, such as access to CGM and insulin pump records, personalization through goal setting and tailored recommendations, as well as insulin bolus calculations [22] were also reiterated by participants in this survey. On the other hand, reminders and rewards i.e., gamification features did not obtain major agreement in this survey despite being present in the literature as key features for diabetes management technology. [22] Several novel app-features were suggested by participants and are worth noting. In fact, the fear of developing eating disorders was mentioned as a barrier to CC. As such, concealing calorie information was suggested to promote a healthier relationship with food using technology. This perspective aligns with existing literature that highlights the importance of automated processes, which demand less input from the individual, as a means to alleviate the burden of treatment in T1D. A review demonstrated that the use of automated insulin delivery systems may reduce food management burden, as it was perceived that it could correct for CC inaccuracy. [23] Similarly, meal entry through photo recognition could alleviate the cognitive burden on individuals with T1D during mealtimes and potentially facilitate full automation. This would enable users to receive bolus dose suggestions simply by taking a picture of their meal, without needing to process additional information. However, it's important to provide users with the option to access breakdowns of carbohydrate estimations and calculations upon request, as it was found to increase their trust in a CC app. Meal entry through photo recognition would also decrease the time required for CC and could potentially alleviate associated burdens. Participants expanded on the mental strain linked with CC, describing it as time consuming, challenging to log multiple small snacks and corrections between meals, and restrictive when “not being able to eat right away,” Another key barrier that was introduced was the limited use of CC apps. Indeed, apps with automated carbohydrate estimation lack integration with a bolus calculator[15], as they are often designed with a weight loss focus. On the other hand, app-based insulin bolus calculators do not offer direct carbohydrate estimation, and still require manual meal entry.[5, 24-26] This underscores participants’ perception that current CC apps lack comprehensiveness. Moreover, existing apps frequently contain unreliable values [27], which can be attributed to users contributing information to the databases or relying on values from foreign databases. Participants reiterated this concern, highlighting unreliable food databases as external sources of errors.

Despite the benefits of CC being well established in the literature [7, 8], respondents perceived a limited utility of CC when it comes to explaining BG levels and glycemic trends due to the multiple dietary and non-dietary factors influencing BG levels. Similarly, a Canadian survey reported similar findings and revealed that 78% of the respondents (n=180) agreed that BG levels fluctuate even with appropriate CC, complicating diabetes management.[28] The most significant barrier reported was the difficulty in accurately identifying and counting carbohydrates. In fact, several research studies documented no significant changes in CC accuracy despite receiving education.[4, 29] Additionally, more than half of this surveys' respondents found determining insulin doses for high-fat meals to be a barrier to CC. Managing the delayed impact of fat on postprandial BG excursions is a well-established challenge in the literature.[30-32] While clinical guidelines recommend meal-time insulin dose adjustments to mitigate the glucose variability due to the impact of dietary fat[33-35], there is no consensus as to which insulin strategies to use. Strategies used to manage glycemic excursions following high-fat meals in T1D are numerous[36] but substantial inter-individual differences exist in insulin dose requirements for fat and individualized advice based on postprandial BG monitoring for multiple hours afterwards is required.[37] As such, the use of a CC app offering the ability to track meal composition, as well as other non-dietary influencing factors can help people with T1D understand BG levels and allow for personalized learning opportunities. While the suggested psychosocial barriers received a lower agreement rate, they are still noteworthy as they were brought up under a different light by participants in the open-ended responses. While CC in the presence of others is not as consequential, the fear of receiving judgment from others or feeling alienated, especially when eating sugary foods, was perceived as a barrier to CC. This was also demonstrated in a cross-sectional analysis of people with T1D perceiving stigma mostly as blame and judgment, including when eating sugary foods.[38] Only 69% of participants reported agreement with app features providing support from HCPs. The interpretation of this finding can be informed by the qualitative analysis shedding light on stigma perception related to interactions with HCP. Participants expressed feeling judged based on their BG values, which generated a fear of "ruining a good day," further complicating their condition management. This sentiment aligns with barriers mentioned by participants regarding the limited support from their HCPs, who heavily focused on glycated hemoglobin levels rather than overall health and had limited knowledge in nutrition. They expressed the need for personalized learning opportunities that could be provided through CC apps by tracking their own trends and accessing educational modules, while maintaining their privacy.

5. Limitations

Our results highlight the perceived barriers and preferred app-features among individuals with T1D and should be interpreted with caution due to certain limitations. The homogeneous sample, with around 84% of the respondents identifying as Caucasian is not representative of most people with T1D and prevents the generalizability of the results. Nevertheless, 16% of this survey's respondents self-identified as Arabs, Asians, Blacks, and Latin Americans, among other ethnicities, as compared to 26% of Canadians self-identifying as belonging to visible minorities according to the 2021 census by Statistics Canada. Further, participant recruitment was extended to include adolescents as well as adults. This allowed including the perceptions of young adults who are transitioning to assuming responsibility for managing their diabetes from caregivers. While surveys as a research method impose limitations on participants' responses and feedback, this was mitigated by incorporating open-ended questions. The thematic analysis provided a deeper understanding of participants' perceptions. Patient-reported outcomes brought additional value to our data and shed light on patient perspectives.

6. Conclusion

This study underscores the specific challenges faced by individuals with T1D and highlights areas for improvement in diabetes management apps. People with T1D require a comprehensive and automated approach to CC, incorporating reliable nutrient values and personalized bolus calculations. A CC app can also address psychosocial barriers by facilitating simple and rapid meal entry via photo recognition, offering in-app peer support, and presenting personalized learning opportunities through tracking factors affecting BG levels. A CC app that integrates these essential elements for T1D management, utilizing validated food databases for accurate estimates, would be unique and novel. Moving forward, it is essential to continuously engage end-users in the development and testing of such an app.

Acknowledgement

We would like to acknowledge the cardiometabolic health, diabetes and obesity research network (CMDO) for the mentorship award to ASB, as well as the contribution of Patient Partners involved in this research project. Material in this manuscript has previously been presented at the 17th International conference on Advanced Technologies & Treatments for Diabetes, Florence Italy [6-9 March 2024] and Vascular Conference, Montreal Canada [25-29 October 2023].

Authors disclosure: A.H. funding from Mitacs Accelerate scholarship. A.K. funding from the

Canadian Graduate Scholarship-Master's Program. AS.B. is a Fond de Recherche du Québec en Santé research scholar. All other authors received no financial support for the research, authorship, and/or publication of this article.

Funding: This work was supported by a Mitacs (grant number #IT31370 ACC).

References

1. Canada D. Diabetes in Canada: Backgrounder. 2021.
2. Canada D. Diabetes Canada 2018 clinical practice guidelines for the prevention and management of diabetes in Canada: Diabetes Canada; 2018.
3. Tascini G, Berioli MG, Cerquiglini L, Santi E, Mancini G, Rogari F, et al. Carbohydrate Counting in Children and Adolescents with Type 1 Diabetes. Nutrients. 2018;10(1):109.
4. Spiegel G, Bortsov A, Bishop FK, Owen D, Klingensmith GJ, Mayer-Davis EJ, et al. Randomized nutrition education intervention to improve carbohydrate counting in adolescents with type 1 diabetes study: is more intensive education needed? Journal of the Academy of Nutrition and Dietetics. 2012;112(11):1736-46.
5. Singla R, Bindra J, Singla A, Gupta G, Gupta Y, Aggarwal S. Automation of insulin bolus dose calculation in type 1 diabetes: a feasibility study. International Journal of Diabetes in Developing Countries. 2022.
6. Sussman A, Taylor EJ, Patel M, Ward J, Alva S, Lawrence A, et al. Performance of a glucose meter with a built-in automated bolus calculator versus manual bolus calculation in insulin-using subjects. Journal of diabetes science and technology. 2012;6(2):339-44.
7. Mehta SN, Quinn N, Volkening LK, Laffel LM. Impact of carbohydrate counting on glycemic control in children with type 1 diabetes. Diabetes Care. 2009;32(6):1014-6.
8. Brazeau AS, Mircescu H, Desjardins K, Leroux C, Strychar I, Ekoé JM, et al. Carbohydrate counting accuracy and blood glucose variability in adults with type 1 diabetes. Diabetes Res Clin Pract. 2013;99(1):19-23.
9. Suh S, Kim JH. Glycemic Variability: How Do We Measure It and Why Is It Important? Diabetes Metab J. 2015;39(4):273-82.
10. Liang X, Wang Q, Yang X, Cao J, Chen J, Mo X, et al. Effect of mobile phone intervention for diabetes on glycaemic control: a meta-analysis. Diabetic medicine. 2011;28(4):455-63.
11. Liu L, Ogwu S. A meta-analysis of mobile health and risk reduction in patients with diabetes mellitus: challenge and opportunity. Journal of Mobile Technology in Medicine. 2012;1(3):17-24.

12. Whitehead L, Seaton P. The effectiveness of self-management mobile phone and tablet apps in long-term condition management: a systematic review. Journal of medical Internet research. 2016;18(5):e97.

13. Bally L, Dehais J, Nakas CT, Anthimopoulos M, Laimer M, Rhyner D, et al. Carbohydrate Estimation Supported by the GoCARB System in Individuals With Type 1 Diabetes: A Randomized Prospective Pilot Study. Diabetes Care. 2016;40(2):e6-e7.

14. Alfonsi JE, Choi EEY, Arshad T, Sammott SS, Pais V, Nguyen C, et al. Carbohydrate Counting App Using Image Recognition for Youth With Type 1 Diabetes: Pilot Randomized Control Trial. JMIR Mhealth Uhealth. 2020;8(10):e22074.

15. Vasiloglou MF, Marcano I, Lizama S, Papathanail I, Spanakis EK, Mougiakakou S. Multimedia Data-Based Mobile Applications for Dietary Assessment. Journal of Diabetes Science and Technology. 2022;17(4):1056-65.

16. Trawley S, Browne JL, Hagger VL, Hendrieckx C, Holmes-Truscott E, Pouwer F, et al. The Use of Mobile Applications Among Adolescents with Type 1 Diabetes: Results from Diabetes MILES Youth-Australia. Diabetes Technol Ther. 2016;18(12):813-9.

17. Hung LC, Huang CY, Lo FS, Cheng SF. The Self-Management Experiences of Adolescents with Type 1 Diabetes: A Descriptive Phenomenology Study. Int J Environ Res Public Health. 2020;17(14).

18. Borus JS, Laffel L. Adherence challenges in the management of type 1 diabetes in adolescents: prevention and intervention. Curr Opin Pediatr. 2010;22(4):405-11.

19. Youth: United Nations; [Available from: https://www.un.org/en/global-issues/youth#:~:text=Who%20Are%20the%20Youth%3F,of%2015%20and%2024%20years.

20. Got Transition® - Transitioning Youth to an Adult Health Care Clinician - Transition Readiness [Available from: https://www.gottransition.org/six-core-elements/transitioning-youth-to-adult/transition-readiness.cfm.

21. Brazeau AS, Messier V, Talbo MK, Gagnon C, Taleb N, Fortier I, et al. Self-reported Severe and Nonsevere Hypoglycemia in Type 1 Diabetes: Population Surveillance Through the BETTER Patient Engagement Registry: Development and Baseline Characteristics. Can J Diabetes. 2022;46(8):813-21.

22. Martinez-Millana A, Jarones E, Fernandez-Llatas C, Hartvigsen G, Traver V. App Features for Type 1 Diabetes Support and Patient Empowerment: Systematic Literature Review and Benchmark Comparison. JMIR Mhealth Uhealth. 2018;6(11):e12237.

23. South CA, Talbo MK, Roy-Fleming A, Peters TM, Nielsen DE, Iceta S, et al. Does insulin delivery technology change our relationship with foods? A scoping review. Diabetes Technology & Therapeutics. 2024;26(2):136-45.

24. Vallejo-Mora M, Carreira M, Linares-Parrado F, Olveira G, Rojo-Martinez G, Dominguez-Lopez M, et al. The CBMDI study: A randomized controlled trial on the effect on metabolic control of adding a bolus calculator to a multiple daily injections treatment in people with type 1 diabetes. Journal of diabetes. 2016;9.

25. Gonzalez C, Picón MJ, Tomé M, Pujol I, Fernández-García JC, Chico A. Expert Study: Utility of an Automated Bolus Advisor System in Patients with Type 1 Diabetes Treated with Multiple Daily Injections of Insulin-A Crossover Study. Diabetes Technol Ther. 2016;18(5):282-7.

26. Ziegler R, Rees C, Jacobs N, Parkin CG, Lyden MR, Petersen B, et al. Frequent use of an automated bolus advisor improves glycemic control in pediatric patients treated with insulin pump therapy: results of the Bolus Advisor Benefit Evaluation (BABE) study. Pediatr Diabetes. 2016;17(5):311-8.

27. M GE, H JK, Brenna JT, S HM. Micronutrient Gaps in Three Commercial Weight-Loss Diet Plans. Nutrients. 2018;10(1).

28. Fortin A, Rabasa-Lhoret R, Roy-Fleming A, Desjardins K, Brazeau A-S, Ladouceur M, et al. Practices, perceptions and expectations for carbohydrate counting in patients with type 1 diabetes – Results from an online survey. Diabetes Research and Clinical Practice. 2017;126:214-21.

29. Gurnani M, Pais V, Cordeiro K, Steele S, Chen S, Hamilton JK. One potato, two potato,… assessing carbohydrate counting accuracy in adolescents with type 1 diabetes. Pediatric Diabetes. 2018;19(7):1302-8.

30. Hanefeld M, Temelkova-Kurktschiev T. Control of post-prandial hyperglycemia--an essential part of good diabetes treatment and prevention of cardiovascular complications. Nutr Metab Cardiovasc Dis. 2002;12(2):98-107.

31. Paterson M, Smart C, Lopez P, Howley P, McElduff P, Attia J, et al. Increasing the protein quantity in a meal results in dose-dependent effects on postprandial glucose levels in individuals with Type 1 diabetes mellitus. Diabetic Medicine. 2017;34(6):851-4.

32. Smart CE, Evans M, O'connell SM, McElduff P, Lopez PE, Jones TW, et al. Both dietary protein and fat increase postprandial glucose excursions in children with type 1 diabetes, and the effect is additive. Diabetes care. 2013;36(12):3897-902.

33. Lodefalk M, Åman J, Bang P. Effects of fat supplementation on glycaemic response and gastric emptying in adolescents with type 1 diabetes. Diabetic medicine. 2008;25(9):1030-5.

34. Panowska E, Blazik M, Groele L. Does the fatprotein meal increase postprandial glucose level in type 1 diabetes patients on insulin pump: The conclusion of a randomised study. Diabetes Technol Ther. 2011;14:1-8.

35. Smart CE, Annan F, Higgins LA, Jelleryd E, Lopez M, Acerini CL. ISPAD Clinical Practice Consensus Guidelines 2018: Nutritional management in children and adolescents with diabetes. Pediatr Diabetes. 2018;19 Suppl 27:136-54.

36. Smith TA, Marlow AA, King BR, Smart CE. Insulin strategies for dietary fat and protein in type 1 diabetes: A systematic review. Diabet Med. 2021;38(11):e14641.

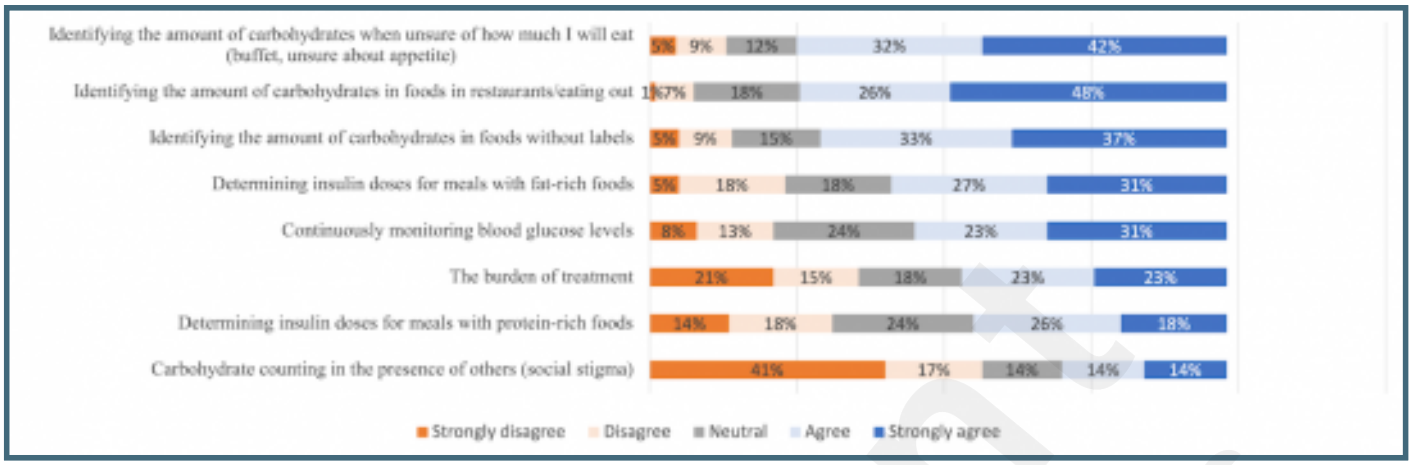
37. Bell KJ, Toschi E, Steil GM, Wolpert HA. Optimized mealtime insulin dosing for fat and protein in type 1 diabetes: application of a model-based approach to derive insulin doses for open-loop diabetes management. Diabetes care. 2016;39(9):1631-4.

38. HOUSNI A, KATZ A, KICHLER JC, NAKHLA M, BRAZEAU A-S. 624-P: Portrayal of Perceived Stigma across Ages in Type 1 Diabetes—A BETTER Registry Analysis. Diabetes. 2023;72(Supplement_1).

Supplementary Files

Figures

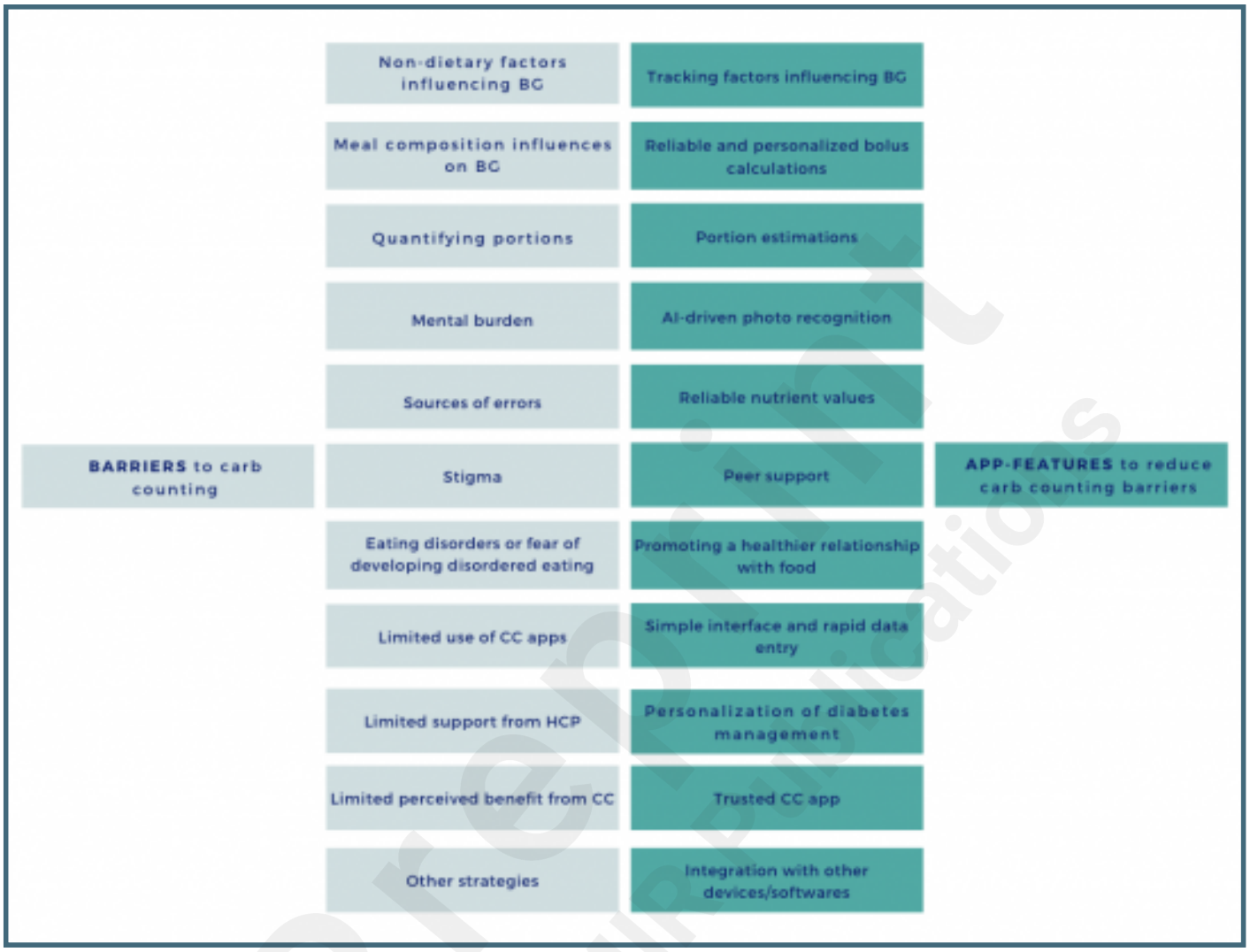
Stacked bar chart of participants' proportion of agreement with suggested barriers to carbohydrate counting.



Suggested app-features were ranked by rate of agreement (4 or 5 on the Likert scale), then cross-referenced in each app (n=16) reported to be used by participants; blue box = app provides the feature.

			Apps reported to be used by partcipants														
		n (%)	Carb Manager	Foodvisor	Lose it	MyFitnessPal	Cronometer	FatSecret	Fitwell	SNAQ	Figwee	Carbs & Cals	Glycemeal	Keenoa	Bolus Calc	Calorie King	Glucicheck	MySugar
Suggested App-features	Viewing the food nutrition label	167 (85%)	■	■	■	■	■			■						■		
	Meal composition quantification	165 (84%)	■	■	■	■	■	■	■	■	■	■	■	■				
	Personalization of the app	151 (77%)																
	Suggestion of insulin bolus doses	145 (74%)													■			
	Unrestricted Support from healthcare professionals	135 (69%)		■														
	Meal logs into a food journal	129 (66%)	■	■	■	■	■	■	■	■	■	■	■	■				
	Community building with app users	93 (47%)	■	■	■	■		■	■									
	Gamification	79 (40%)	■		■	■												

Emerging themes of reported barriers to carbohydrate counting and app-features perceived to reduce these barriers, derived from the qualitative analysis.



Multimedia Appendixes

Survey questions.
URL: http://asset.jmir.pub/assets/0f6f0bdcdbb65bc18dbb72feb6f7a33e.docx

Theme description derived from the qualitative analysis.
URL: http://asset.jmir.pub/assets/c4ef35907e6599a8c257026dd6f439d7.docx