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"My Friend Diabetes Carbohydrate-Bolus Calculator": User Experiences of a Bolus Calculating Carbohydrate Counting Mobile App for People with Type 1 Diabetes

ABSTRACT

Objective: Meal management in Type 1 Diabetes (T1D) has barriers such as miscalculation of doses, insufficient carbohydrate counting and numeracy skills. "My Friend Diabetes Carbohydrate Bolus Calculator" mobile app was developed as a hybrid version of nutrition apps and insulin titration apps to calculate meal's carbs and the matching bolus dose. This study investigates facilitator role of the app on lives of people with T1D.

Materials and methods: People with T1D or their caregivers were recruited from children diabetes foundation social media accounts, and they answered an online survey which examines the effects of the app on carbohydrate counting, diabetes management, and the usability of the app with 17 Likert-type questions (5-point). Descriptive and non-parametric tests were performed to analyze responses.

Results: Of the 165 people who completed the survey, 58 (35.2%) had T1D, 107 (64.8%) had relatives with T1D; 87 (52.7%) participants were female, the mean age was 13.1 ± 8.9 years, and the mean duration of diabetes was 4.72 years. Of the participants, 130 used the app and agreed that the app improved the users' meal management, diabetes management, carbohydrate, and dose calculations (Mean score = 4.38 ± 0.57). They were more confident in the dose calculation, freer in the food choices, and more confident in diabetes care because of the app (Mean score = 4.46 ± 0.57).

Conclusions: ''My Friend Diabetes Carbohydrate-Bolus Calculator'' mobile app improved T1D management. Diabetes teams can reach more people through mobile apps and improve their clinical outcomes. (Clin Diabetol 2023; 12; 1: 53–59)

Keywords: bolus dose, carbohydrate counting, mobile app, type 1 diabetes

Introduction

Despite advances in insulin therapy and diabetes technologies, less than 50% of people with type 1 diabetes (T1D) achieve the desired glycemic goals and clinical outcomes [1]. One of the most challenging areas in T1D care is the management of postprandial glucose. The most decisive factors in the management of the postprandial period are carbohydrate counting (CarbC) and matching the effect of bolus insulin with the effect of nutrients on blood glucose. While advanced carbohydrate counting training (CarbCT) provides significant benefits, there are certain barriers in CarbC such as misinterpretation of foods' carbohydrate values [2]. Additionally, there are barriers in calculating bolus doses — a problem that varies according to the numeracy skills of the individuals [3].

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T1D management has been improved by 1) nutrition apps [4] that provide information about carbohydrates and other nutrients, 2) physical activity apps [5]; 3) glucose monitoring apps that show continuous glucose monitoring data and blood glucose measurements; 4) insulin titration apps [6] that calculate basal, prandial and correction doses, and 5) insulin delivery apps that work with smart pens or pumps [7]. However, most of these apps are only available in certain countries or regions and cannot be downloaded worldwide.

We have developed the "Arkadasim Diyabet Karbonhidrat Bolus Hesaplayici (My Friend Diabetes Carbohydrate Bolus Calculator)" mobile app for people with diabetes to help them overcome the challenges of CarbC and calculating bolus doses. The app was developed voluntarily by a small team of a software developer, a dietitian, a medical student with type 1 diabetes and 2 pediatric endocrinology professors from Koc University pediatric diabetes clinic. The app was developed as a hybrid version of nutrition apps and insulin titration apps according to the classification of digital health apps used in diabetes management in the consensus report by the European Association for the Study of Diabetes and the American Diabetes Association Diabetes Technology Working Group published in 2020 [7]. The app consists of two calculators: the carbohydrate calculator, in which the carbohydrate contents of foods and meals are calculated by entering the units and amounts, and the bolus calculator that calculates insulin dose according to the entered carbohydrate amount in grams, measured glucose (mg/dL), target glucose (mg/dL), insulin sensitivity factor, carbohydrate/insulin ratio, content of protein and fat. A nutrition database for this app was created using data from the Turkish Dietetic Association, the Nutrition Information System, the United States Department of Agriculture Nutrient Composition Database, Nutrition facts labels, and ISPAD guideline [8]. The database includes staple foods, vegetables, fruits, meats, dairy products, packaged products, recipes with one carb-containing ingredient. Since the amount of carbohydrates in recipes containing many carbohydrate ingredients may vary according to the ratio of the ingredients, they are not included in the database. Since the first target audience of the application was Turkish people, Turkish foods were in the majority on the list. The database, which is a record of food names, unit weights, and carbohydrate values per unit weight, is presented to the user in measurement units such as tablespoons, pieces, and glasses for user convenience. In addition to choosing a meal from the database, a food with a known carbohydrate value can be included in the calculation by directly entering the value into the calculator. The calculated total carbohydrate amount is transferred to the bolus calculator in the app, and the bolus doses are calculated according to formula 1*. In cases of having fat rich meals, users can use the high fat toggle according to their judgement and the calculated dose for carbohydrates is increased by 20% [9]. When the bolus dose has been calculated, the app suggests how many minutes before the meal the bolus dose should be administered according to the glucose value [10] (Fig. 1). In the "About" section of the app, information regarding target glucose values, insulin sensitivity factor, and carbohydrate/insulin ratio definitions, contribution of proteins and fats, as well as information on basics of CarbC is available with references.

$$Bolus\ Dose = \frac{(\text{Glucose Value} - \text{Target Glucose Value})}{\text{Insulin Sensitivity Factor}} + \frac{Carbohydrate\ Amount}{Carbohydrate\ Insulin\ Ratio}$$

*Formula 1

The app was published with data of 200 nutrients in the Apple Store in October 2020. It became available with only Turkish language option on both the Google Play Store and AppStore in December 2020. One month later, the database was upgraded with the addition of 400 more nutrients. In addition, we provided our educational materials and guidelines, which contain up-to-date information on the treatment of T1D, in PDF format under the "useful resource" section. The app has a tutorial section to teach users how to navigate and use the app. We gathered feedback from the users by introducing "request a food" feature which helps us to add those foods that the users were not able to find in the database. According to the data collected from the database services provided by Google, the app was being used by 450 different people every day and 3000 people each month by the end of January 2020. At the end of the first week and the first month, the app ranked number 1 and number 3 in medical app category of AppStore in Turkey, respectively. The user numbers grew steadily in the following months. On its first anniversary, the numbers had increased to 1000 different daily users and 5000 different users per month. We also promote the app in our clinic and give a hand-out with the instructions for the app to our patients. The fact that the average monthly retention rate (3.5% in mobile medical apps globally) is 10–12% for our app shows that our application serves the determined need well [11]. In this study we aimed to assess the benefits and shortfalls of the app, conducting an online survey about the app's effects on people's lives and diabetes management.

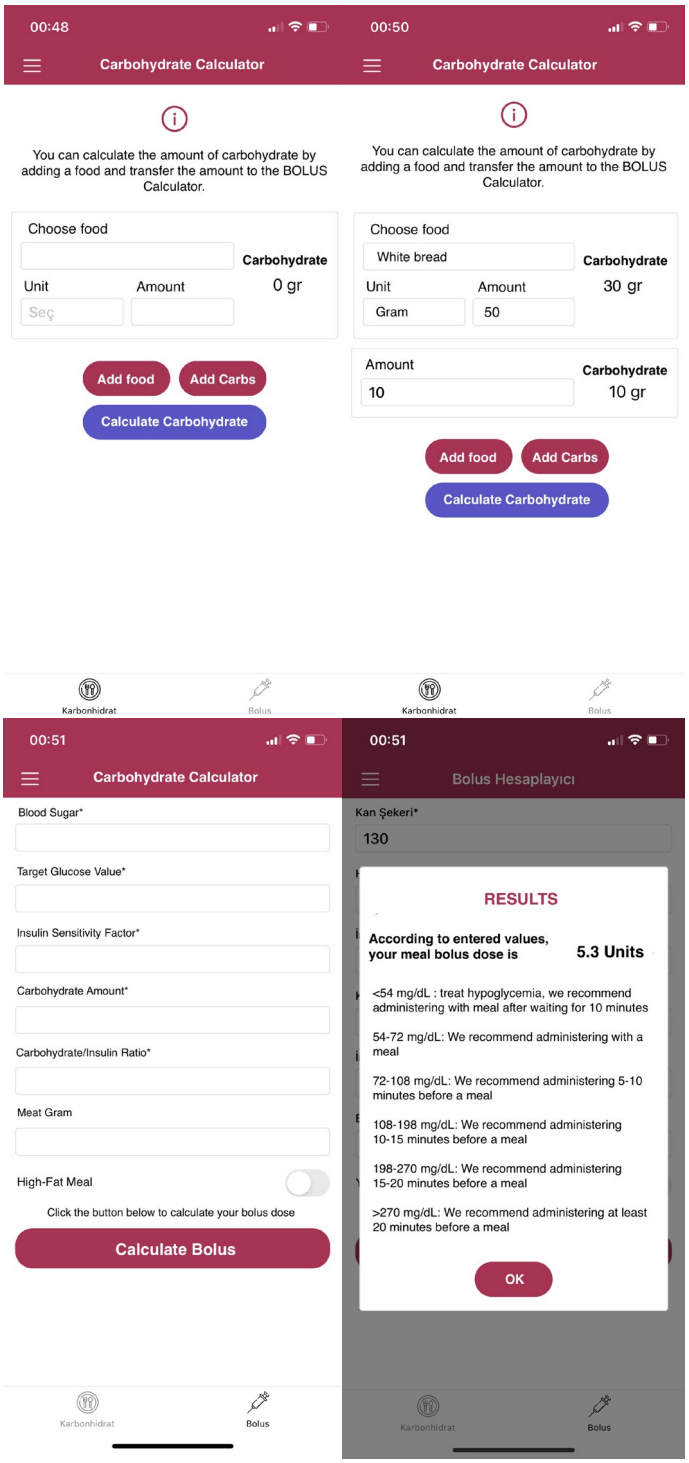

Figure 1. Screenshots of the App
All writings were translated from Turkish for this figure. Upper left: Add food feature allows users to choose food from the database with units and amounts. Upper left: Add carbs feature allows users to add Carb amounts manually. Lower Left: Bolus calculator needs to be filled out. Lower Right: when the bolus dose is calculated, result screen shows the dose and recommended dosing time

Materials and methods

Measures

In this cross-sectional study, the survey link was announced twice on Children Diabetes Foundation social media accounts (Instagram and WhatsApp) with 5500 followers combined in October 2021. After the first announcement, it was waited for 2 weeks, the second announcement was made, and 2 weeks later, the study was terminated at the end of a 1-month period with 212 responses. Response rate could not be

calculated since it is not known how many people saw the survey announcement. The survey was conducted via Qualtrics. The inclusion criteria were having T1D or being a caregiver of a person with T1D. Demographic characteristics included age, gender, relationship with diabetes (I have T1D, I have a first degree relative with T1D, other), years with diabetes, CarbCT status (Completed, not completed, never received any training), use of CarbC in T1D management status (yes/no), use of the app status (yes/no). The responders' views on the difficulty of CarbC, the liberating features of CarbC, and self-assessment of meal management competencies were examined with 3 questions (10-point scale). Only app-user responders answered questions about the effects of the app on CarbC, diabetes management, daily life, and the usability of the app through 17 Likert-like questions (5 options, 1: strongly disagree, 2: disagree, 3: undecided, 4: agree, 5: strongly agree). App-user responders are asked to report if there is any problem they experienced in the app with an open-ended question. The study was conducted according to the Declaration of Helsinki principles and it was approved by the Institutional Research Ethics Committee (2022.069.IRB3.022).

Statistical analyses

Descriptive statistics (N, %, mean, standard deviation [SD]) were calculated for age, gender, responders' relationship with T1D, duration of T1D, CarbCT, CarbC, and app usage statuses. Answers of 17 Likert-like questions were transformed to numbers from 1 to 5 and descriptive analyses were applied. The Independent T-test is used for 3 questions with 10-point scale according to app usage status and Kruskal-Wallis test is used for 3 questions with 10-point scale according to CarbCT status were used for parametric and non-parametric analyses to make intergroup comparisons in IBM-SPSS v28.

Results

Of 212 responses, 165 responses have satisfied the inclusion criteria. Of these 165 responders, 58 (35.2%) had T1D, 107 (64.8%) were caregivers of children with T1D, while 87 (52.7%) of the responders were female, the mean duration of diabetes was 4.72 years and the mean of the age of the people with T1D was 13.1 ± 8.9 years. Of the responders, 100 (60.6%) had completed the CarbCT, 47 (28.4%) had not completed CarbCT, and 18 (11%) had not received any CarbCT. As can be seen in table 1, a total of 150 (90.9%) responders counted carbohydrates, while 15 (9.1%) did not; 130 (78.8%) responders reported that they used the application, while 35 (21.2%) responders did not. Of the 130 people who used the app, 16 (12.3%) stated they had experienced only minor problems such as duplicates of some foods in the database and the unexpected effects of fried foods on glycemia.

Table 1. Characteristics of Responders

	All responders (n = 165)
Duration of T1D in years, median (range)	3 (0.1, 38)
Age of the people with T1D in years, mean (SD)	13.1 (8.9)
Responders' relationship with T1D, % (n)	
Has T1D	35.20% (58)
Caregivers of children with T1D	64.80% (107)
Gender of people with T1D, Female, % (n)	52.70% (87)
Carbohydrate counting training, % (n)	
Completed	60.60% (100)
Did not complete	28.40% (47)
Never received any training	11% (18)
Carbohydrate counting in diabetes management, % (n)	
Yes	90.90% (150)
No	9.10% (15)
Using the application, % (n)	
Yes	78.80% (130)
No	21.20% (35)

T1D — type 1 diabetes

Those who used the app had significantly less difficulty in counting carbohydrates compared to those who did not use the app ($p < 0.001$, n = 130 vs. n = 35). The responders who had received CarbCT had significantly less difficulty in CarbC than those who had not completed CarbCT or those who had not received any training on CarbC (n = 100 vs. n = 47 vs. n = 18, $p < 0.001$). Among the application users, those who had received complete CarbCT stated that they knew more about CarbC than those who had received incomplete or no training (n = 85 vs. n = 33 vs. n = 12, $p < 0.001$).

App users responded to 17 questions on a 5-point Likert scale, as seen in Figure 2. The highest scoring questions were those stating that carbohydrate counting was a useful method (the mean score: 4.86 ± 0.50) and that the app made people's lives easier (the mean score 4.56 ± 0.63). The 4 questions (questions 2, 7, 10, 13) examining the app's effects on life and people's attitudes stated that the app facilitated people's life, provided freedom in food choice, confidence in the dose calculation and self-confidence about diabetes (the mean score: 4.46 ± 0.57). The 5 questions (questions 5, 6, 9, 14, 15) examining the contribution

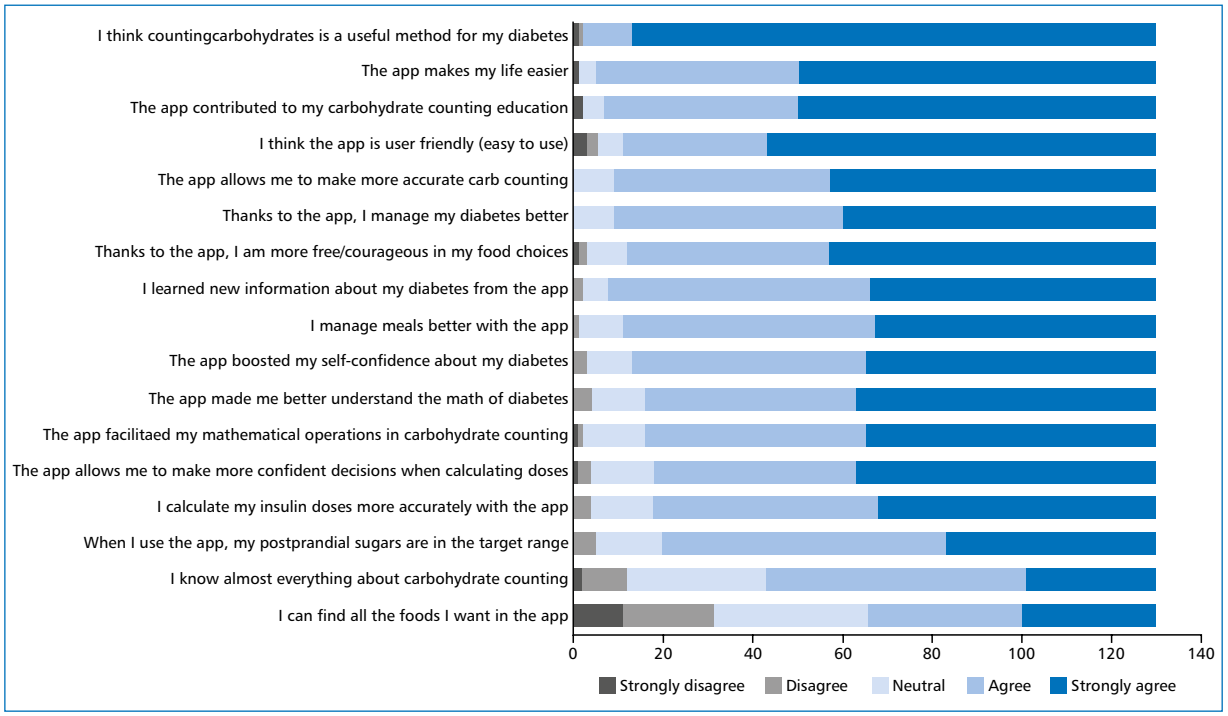

Figure 2. Responses of 130 App-Users to the Questions about the App, Listed According to Mean Score (from High to Low)

of the app to metabolic control stated that the app improved the user's meal and diabetes management and provided better carbohydrate counts and dose calculations. (The mean score was 4.38 ± 0.58). The 3 questions (questions 11, 12, 14) examining the effect of the application on numeracy skills in T1D management stated that the app facilitated understanding of the mathematics of diabetes and ratio, proportion, and summation calculations (the mean score was 4.35 ± 0.65). The lowest score was given to the question stating that users could find the foods they wanted in the app (the mean score 3.4 ± 1.24).

Discussion

Providing structured CarbCT contributes to the confidence and ease of CarbC for people with T1D. The responders who filled out our survey demonstrated the strongest agreement in the areas of the usefulness of CarbC and the facilitating role of the app in their lives. Accordingly, the highest scored questions were those stating that carbohydrate counting was a useful method and that the app made people's lives easier. The questions examining the app's effects on life and people's attitudes stated that the app facilitated people's life, provided freedom in food choice, confidence in the dose calculation and self-confidence about diabetes.

Improvement of glycemic control is possible only if the person with T1D has access to accurate, sufficient, and understandable information as well as them complying with and maintaining the treatment [12]. This mobile app aims to facilitate nutrition management, which is one of the most important pillars of diabetes management.

The app is aimed at providing clinical knowledge to many people with T1D who have not received comprehensive CarbC or bolus dosing training and to contribute to their diabetes practices. It also aims to encourage people with T1D and their families, especially those who did not have access to experienced diabetes teams, to start CarbC by themselves and motivate them to receive further CarbCT. In addition to these primary aims, children with T1D who are followed up at our institution and their caregivers were informed about how to use the app during diabetes education, enabling them to use the app actively, and it was observed that the app also reduced the clinical burden of the diabetes team.

In a study conducted by the Ministry of Health in Turkey, the level of national health literacy was observed as 30.9% inadequate, 38.0% problematic-limited, 23.4% adequate and 7.7% excellent. It has been determined that limited health literacy (insufficient and problematic-limited) stands out as an important public health problem, affecting seven out of ten people in the country [13]. There are serious difficulties in applying diabetes education to support understanding in people with T1D and their families with insufficient

health literacy. The My Friend Diabetes Carbohydrate Bolus Calculator aims to provide convenience for people who do not have sufficient health literacy or numeracy. In our clinical practice, we see that even families who have not received any CarbCT improved their dose calculation skills by using the app, and those who do not have the required numeracy and nutritional knowledge also improve themselves. The app offers a good solution to the nationwide challenge for people to reach nutritional carbohydrate values and provides a resource for users to consult. While the survey shows the app's contribution to the training process, we also observed that the app increases the gains throughout the training process that begins in the clinic and continues at home, thus building a bridge between them. Hence, we are able to realize our vision of improving T1D management on a national scale and becoming a "clinic without wall".

Although responders find the app user-friendly, they acknowledged that finding the carbohydrate values of the foods which they search for in the app was challenging. The lowest score was given to the question stating that users could find the foods they wanted in the app, which suggests that the nutrition database needs to be improved.

As limitations of this study, we could not calculate the response rate due to not knowing how many people have seen our announcements. We also did not know how many participants were followed up at our clinic since the recruitment was from social media. This study does not represent people with T1D in Turkey since the sample size and power were not calculated and the recruitment was not appropriate to conduct a representative study. All descriptive information was self-reported, and we had limited knowledge about participants' CarbCT status, CarbC skills and how much they have used the app. Number of people with no CarbCT was low to represent this population. Although this study shows facilitative role of this app in the people's lives, it does not provide strong evidence for effect of the app on glycemic control. A quantitative study should be conducted to test the effectiveness of the app further on glycemic metrics [14]. The questionnaire also needs a validation with a larger group of app users who provides strong evidence of app use.

Regional or national restrictions of other diabetes apps [4–7] hinder people in accessing assistance with T1D management. This situation has led us to seek new solutions and develop this app. The app can be downloaded for free from the App Store and Google Play Store worldwide, unfortunately only with Turkish language option. Perhaps one of the most important benefits of the app is that people with T1D who do not have access to a diabetes team or who live in areas where health services are limited have free access to the app. Diabetes teams can build similar apps with local/ /national nutrition databases and increase the range of people they reach. Providing accessible knowledge and methods for people with T1D outside the clinic may overcome barriers in the management of T1D. Clinical efforts can significantly influence people's lives if such goal-oriented technologies are provided and encouraged more.

We plan to improve our nutrition database according to users' feedback and increase the number of informative articles and guidelines in the application. Making the app more widely used by adding new language options and promoting the app is another important goal to achieve nationwide improvement and worldwide impact in T1D care.

Conclusions

We shed light on the difficulties in T1D management with our clinical knowledge through the easily accessible "My Friend Diabetes Carbohydrate Bolus Calculator" application, and we can help people with T1D and their families even outside the clinic. As our observations and users' feedback show, the mobile app amplifies our clinical efforts, increases its impact, and the range of people we can help.

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Conflict of interest

None declared.

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