

Carbulin: A Comprehensive Mobile Application for Advanced Carbohydrate Counting and Diet- and Insulin-Regimen Planning for Type 1 Diabetic Patients

Seyedeh Maryam Abdollahzadeh¹, Meysam Ghanaatpishe², Mesbah Shams^{3*}, Hossein Moravej⁴, Seyed Mohammad Mazloomi¹

ABSTRACT

Nowadays, the introduction of the so-called ‘diabetes technology’, either hardware/device or software, to different aspects of day-to-day living in patients with diabetes aims to improve blood glucose control and various lifestyle features. The coordination of vast context of diabetes education/training, particularly in the area of medical nutrition therapy, is considered as a great concern. On the other hand, Iranian food culture consists of a set of traditional dietary patterns and food consumption habit. The study was aimed to develop “*the Comprehensive Mobile Application of Advanced Carbohydrate Counting and Diet- and Insulin-Regimen Planning*” to help type 1 diabetic patients, improving their health status. The programming language of Kotlin, JavaScript, Node JS, and HTML5 was used for the mobile app development. The app was developed with the following abilities: 1) educating users on different aspects of disease control including, updated general treatment guidelines on physical activity, medical nutrition and insulin therapy, stress management, and the patient’s specific goals and dietary needs, 2) performing advanced carbohydrate counting using both picture-represented and kitchen-scale of carbohydrate foods as well as traditional Iranian foods, 3) recommending the patient’s specific insulin dose, either short- or rapid-acting, based on the carbohydrate content of the selected meal or the selected amount of Iranian foods, 4) recommending the personalized insulin dose needed for decreasing the high blood glucose levels, and 5) performing 3 and 4 simultaneously. Developing Carbulin was an effort to increase type 1 diabetes self-management using the traditional Iranian dietary pattern and menu.

Citation: Abdollahzadeh SM, Ghanaatpishe M, Shams M, Moravej H, Mazloomi SM. Carbulin: A Comprehensive Mobile Application for Advanced Carbohydrate Counting and Diet- and Insulin-Regimen Planning for Type 1 Diabetic Patients. *J Biomed Phys Eng.* 2022;12(3):319-324. doi: 10.31661/jbpe.v0i0.2104-1323.

Keywords

Mobile Applications; Diabetes Mellitus; Insulin; Carbohydrates

Introduction

Diabetes mellitus (DM), as a third leading cause of death worldwide, is a complex, chronic metabolic disorder, demanding sustained medical care with multifactorial risk-reduction strategies (further than glycemic control) [1]. With the increasing trend of global incidence and the ongoing high prevalence rate of DM in the Middle East and North Africa Region (MENA), estimated by International Diabetes Federation [2], the concern doubles for the affected nations as well.

Iran is an aging developing country, experiencing transitional peri-

¹PhD, Nutrition Research Center, School of Nutrition and Food Sciences, Shiraz University of Medical Sciences, Shiraz, Iran
²MSc, Shiraz University of Medical Sciences, Shiraz, Iran
³MD, Endocrinology and Metabolism Research Center, Shiraz University of Medical Sciences, Shiraz, Iran
⁴MD, Neonatal Research Center, Department of Pediatrics, Shiraz University of Medical Sciences, Shiraz, Iran

*Corresponding author: Mesbah Shams
Endocrinology and Metabolism Research Center, Shiraz University of Medical Sciences, Shiraz, Iran
E-mail: shams@sums.ac.ir

Received: 2 May 2021
Accepted: 27 May 2021

od with the increasing health burden of non-communicable diseases, especially diabetes, [3] and has an approximate number of 7800 children and adolescents 0–19 years with type 1 DM [2].

Besides, regarding the proportions of type 1 DM (11.4%) based upon the first Nationwide Diabetes Report of National Program for Prevention and Control of Diabetes (NPPCD-2016), further updated novel prevention and management strategies are still demanded to alleviate the correspond economic burden on national health care system [4, 5].

Moreover, pharmacotherapy, regular physical activity, and medical nutrition therapy have long been demonstrated to have integral roles in achieving individualized treatment goals in diabetes chronic management [6, 7]. The coordination of vast context of diabetes self-management, education/training, and treatment planning with active participation of the patient (and his/her family), particularly in the area of carbohydrate counting regarding insulin regimen and the development of an individualized eating plan, is highly recommended [7].

On the other hand, culinary culture of an individual country, as a collection of human dietary behavior, traditional diet, and food consumption pattern, is reliant on the geographical environment and available food items. Iranian dietary culture is therefore, different from those of western countries [8]. Such issue should be addressed carefully during menu design and dietary planning for general population and patients, both in-person and virtual self-management education.

The introduction of the so-called ‘diabetes technology’, either hardware/device or software, to different aspects of day-to-day living in patients with diabetes aims to improve blood glucose control and various lifestyle features. Though traditionally attributed to the devices, by which either insulin injected or blood glucose monitored, diabetes technology has more recently been ascribed to hybrid device(s)

with the two functions or software(s), facilitating diabetes self-management education and support. Proposed softwares are further recommended to be individualized based on the patient’s needs, desires, skill level, and availability of devices [9].

Though several efforts have been made to develop the expert system software addressing diabetes self-management education (considering diet/nutrition) particularly in the last two decades [10-12], recent advances in smartphone technology and the proliferation of data connectivity have led to introduce mobile application (app) for the purpose [13-15].

Any effort in developing disease-specific self-management software/app should preferably be accompanied by the use of the pertinent national dietary pattern and menu [8]. In this regard, Carbulin is primarily developed for dietary management of type 1 DM and also helps the user improve his/her knowledge and nutritional skills in advanced carbohydrate counting in order to achieve and maintain optimal glycemic control, considering Iranian menu. It also enables the user to prevent and deal with acute or chronic complications associated with the disease (ex: hyperglycemia, hypoglycemia, microvascular and macrovascular complications).

Material and Methods

Carbulin programming language

Carbulin android application is in Kotlin programming language and is compiled with Android SDK Version 25. Latest programming design patterns have been incorporated into the application to ensure enhanced stability, optimal performance, and great maintainability.

Javascript and NodeJS are used as the programming language and the Javascript runtime engine of the Carbulin server, respectively. The server uses a request response methodology to communicate with the application in a client-server fashion. MongoDB is further

served as an open source high performance NoSQL document based database management system.

Carbulin server holds all the information about diabetes, its pharmaceutical and non-pharmaceutical management options, food ingredients, and user characteristics entered, both about their self and about their insulin regimen. Aside from giving the information to the users by browsing, data on the current blood sugar level, measured by glucometer, as well as multiple food items and/or traditional Iranian menu can be given to the app to find out how much insulin has to be injected to the user for normalizing the blood glucose level. In this regard, needed personalized data is either taken in the first time or asked to be confirmed for other times.

The energy and carbohydrate contents of different food items given in the Food Data Central of U. S. Department of Agriculture, food album, and standard Iranian menu were also applied, where needed.

Results

The app was developed to provide the following features, as discussed below:

Anthropometrics, target treatment goals, and nutritional requirements

To get started, the user (the patient or his/her parent/caregiver) has to enter the age, gender, anthropometric measures (body height and weight), type of diabetes, and insulin regimen (including, insulin type and unit administered by physician). Data either on children and adolescents' growth status or on adults' obesity status (i.e. height-for-age (H/A) and body mass index (BMI)-for-age (BMI/A) z scores, and the relevant interpretation for the former or BMI, percentage of body fat, and the related elucidation (based upon World Health Organization (WHO) criteria or Durenberg equation for the latter)) can then be visualized to the user. In the case of lower or higher than

the appropriate recommended values for each, the app alerts, represents the normal ranges of the parameter, and gives him/her one- or two-sentence advisory statement.

In the next section of the app, the patient-specific glycemic targets including, target preprandial, postprandial, and bedtime blood glucose (BG) concentrations (mg/dL and/or mmol/L) and glycosylated hemoglobin (HbA1c) (%) and frequency of self-blood glucose monitoring (SBGM) are emerged on the screen to remind the user the importance of achieving glycemic control. Other therapeutic objectives recommended to minimize the risk of vascular complications (including, high and low density lipoprotein cholesterol (HDL-C; LDL-C; mg/dL), triglyceride (TG; mg/dL), and blood pressure (BP; mmHg)) can be further visualized by selecting 'view more clinical targets' as well.

Suggested daily requirements of energy (kcal) and macronutrients (including, protein, carbohydrate and fat (g and kcal % of total kcal)) tailored to individual needs will be recommended by the app then.

Practical insulin use recommendation

The main section of Carbulin is devoted to 'insulin calculation'; initially, Carbulin asks the user to refresh/confirm the information on the insulin type and dose and to enter the fasting blood sugar (FBS) of the two previous days as the predictive variable of general glycemic control. In case of poorly controlled FBS levels, the app alerts and gives an advisory statement to visit physician for providing a more sustainable glycemic control. Otherwise, the app proceed to ask the user for the particular purpose as follows: 1) recommending the patient's specific insulin dose (either short- or rapid-acting), based on the carbohydrate content of the selected foodstuff or Iranian meals, 2) recommending the personalized insulin dose (either short- or rapid-acting) needed for decreasing the high blood glucose levels, or 3)

performing both 1 and 2, simultaneously.

In case of selecting the first path, the user can further choose different kinds of food items categorized into 5 different food groups of grains, fruits, vegetables, dairy, proteins, according to MyPlate defined by Food and Nutrition Service of US Department of Agriculture (USDA). High carbohydrate items entitled 'sometimes foods', and traditional Iranian meals can also be visualized by either entering the food name or turning the relevant filter of each food group 'on'. The amount of each food item can be selected based on either of two different scales of house-hold scales, including glasses and tablespoon with standard colored picture of food album, or gram. The respective carbohydrate content of the selected foodstuff, will then be summed to calculate pre-meal bolus insulin by the use of insulin to carbohydrate ratio. Different amounts of a standard portion of the Iranian food, can also be selected as a single food of the selected food list.

If high BG is measured, then the second path can be chosen. Importing the current BG, the insulin dose recommended by Carbulin can be visualized, regarding target BG for the specified age span by the use of correction factor.

In case of selecting the third path, the insulin dose required for effective BG control of prandial glucose, when high BG is measured, can be visualized.

Diabetes-related information

By browsing Carbulin, a section can be dedicated to increase the knowledge and self-management skills of the user about diabetes. Users are educated on the disease moiety, its particular acute or chronic complications, the probable causes, and the relevant prevention and management considerations of each. Different aspects of disease control including, updated general international guidelines on physical activity, medical nutrition and insulin therapy, and stress management can be visualized to the user by selecting the appropriate

topic.

Data on different types of insulin, onset and peak of action, usual effective duration, recommended time to monitor the effect of each, and instruction and the correct choice of insulin injection sites in different situations can be further browsed by the user as a result of attaining the educational purpose of Carbulin.

Additional drug information on the indication, site and mechanism of action, dosages (for pediatrics or adults), possible associated side effects, interaction, warning, precaution, and nutrition consideration can also be found in the section of 'pharmaceutical care of type 2 diabetes'.

Discussion

Identified as one of the biggest challenges faced by the patients with type 1 diabetes (and/or their parents/caregivers) to overcome, carbohydrate counting approach for meal planning, regarding intensive, but flexible insulin regimen is considered as the basis of the glycemic control and disease management. In this regard, the present study suggests the opportunity for developing a mobile app for diabetes self-management education and support. Considering nation-specific differences in dietary pattern, the proposed app is expected to be widely used by Iranian patients, but not non-native users. Extensive directions are in progress focusing on the adoption of a randomized double-blinded design to test the hypothesis of the efficacy of such intervention before its wide use.

Conclusion

The present mobile app is proposed to increase diabetes self-management and to cope with the most important challenge (i.e. attaining glycemic control) to lower the risk of acute and chronic complications and improve longevity and quality of life. Though as an effort to introduce a user-friendly app, limited skill of the users may still restrain its use. Incorporating national Iranian recipes, however,

makes the app more suitable for the user.

Acknowledgment

This study was entirely financed by Shiraz University of Medical Sciences, project no.97-01-01-17092. The authors would like to thank Younes Khoshghadam.

Authors' Contribution

SM. Abdollahzadeh and M. Ghanaatpishe conceived the idea and also designed and developed the application. SM. Abdollahzadeh developed the first version of the proposal and M. Shams, H. Moravej, and SM. Mazloomi reviewed and approved the final version. M. Shams, H. Moravej, and SM. Mazloomi contributed to the application design as well. The research work was supervised by M. Shams. The manuscript was drafted by SM. Abdollahzadeh. All authors reviewed and approved the final manuscript.

Ethical Approval

The ethics committee approval (IR.SUMS.REC.1398.1016) was obtained from the institutional ethics committee at Shiraz University of Medical Sciences.

Funding

This study was financially supported by Shiraz University of Medical Sciences (project no. 97-01-01-17092).

Conflict of Interest

None

References

1. American Diabetes Association. Introduction: Standards of medical care in diabetes-2021. *Diabetes Care*. 2021;**44**(Supplement 1):S1-S2. doi: 10.2337/dc21-Sint. PubMed PMID: 33298409.
2. International Diabetes Federation. IDF diabetes atlas ninth. Dunia: IDF; 2019.
3. Danaei G, Farzadfar F, Kelishadi R, Rashidian A, Rouhani OM, et al. Review Iran in transition. *Lancet*. 2019;**393**(10184):1984-2005. doi: 10.1016/S0140-6736(18)33197-0. PubMed PMID: 31043324.
4. Esteghamati A, Larijani B, Aghajani MH, Ghaemi F, Kermanchi J, Shahrani A, et al. Diabetes in Iran: prospective analysis from first nationwide diabetes report of National Program for Prevention and Control of Diabetes (NPPCD-2016). *Sci Rep*. 2017;**7**(1):1-10. doi: 10.1038/s41598-017-13379-z. PubMed PMID: 29044139. PubMed PMID: PMC5647418.
5. Nasli-Esfahani E, Farzadfar F, Kouhnavard M, et al. Iran diabetes research roadmap (IDRR) study: a preliminary study on diabetes research in the world and Iran. *J Diabetes Metab Disord*. 2017;**16**(1):1-8. doi: 10.1186/s40200-017-0291-9. PubMed PMID: 28239599. PubMed PMID: PMC5316224.
6. Early KB, Stanley K. Position of the Academy of Nutrition and Dietetics: the role of medical nutrition therapy and registered dietitian nutritionists in the prevention and treatment of prediabetes and type 2 diabetes. *J Acad Nutr Diet*. 2018;**18**(2):343-53. doi: 10.1016/j.jand.2017.11.021. PubMed PMID: 29389511.
7. Paswan SK, Verma P, Raj A, Azmi L, Shrivastava S. Role of nutrition in the management of diabetes mellitus. *Asian Pac J Health Sci*. 2015;**2**(4):42-7.
8. Mazloom Z, Abdollahzadeh SM, Ashktorab V, Hashemi B, et al. Metabolic Nutri-Expert System: A Comprehensive Tool for Achieving Metabolic Control of Inborn Errors of Amino Acid Metabolism. *Int J Comput Appl*. 2018;**182**(10):1-5. doi: 10.5120/ijca2018917711.
9. American Diabetes Association. 7. Diabetes technology: standards of medical care in diabetes—2019. *Diabetes Care*. 2019;**42**(Suppl 1):S71-S80. doi: 10.2337/dc19-S007. PubMed PMID: 30559233.
10. Hashemi B, Javidnia H. An approach for recommendations in self management of diabetes based on expert system. *Int J Comput Appl*. 2012;**53**(14):6-12. doi: 10.5120/8487-2431.
11. Jha SK, Singh DK. Development of knowledge Base Expert System for Natural treatment of Diabetes disease. *Int J Adv Comput Sci Appl*. 2012;**3**(3):44-7. doi: 10.14569/IJAC-SA.2012.030308.
12. Kovaszni G. Developing an expert system for diet recommendation. International Symposium on Applied Computational Intelligence and Informatics (SACI); Timisoara, Romania: IEEE; 2011. p. 505-9.
13. Petersen M, Hempler NF. Development and testing of a mobile application to support dia-

- betes self-management for people with newly diagnosed type 2 diabetes: a design thinking case study. *BMC Med Inform Decis Mak.* 2017;**17**(1):1-10. doi: 10.1186/s12911-017-0493-6. PubMed PMID: 28651639. PubMed PMID: PMC5485734.
14. Jeon E, Park HA. Development of the IMB model and an evidence-based diabetes self-management mobile application. *Healthc Inform Res.* 2018;**24**(2):125-38. doi: 10.4258/hir.2018.24.2.125. PubMed PMID: 29770246. PubMed PMID: PMC5944187.
15. Tuah NM, Yoag A, Ahmedy F. My Diabetes—the Gamified Application for Diabetes Self-Management and Care. *Computers.* 2021;**10**(4):50. doi: 10.3390/computers10040050.