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Use of apps for physical activity in type 1 diabetes: current status and requirements for future development

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Abstract: Smartphone technologies, and the applications (apps) that they host, are developing rapidly mainly with regard to communication, information processing, design, features and connectivity with other devices. Technologies used in modern treatment modalities and monitoring of type 1 diabetes are also rapidly evolving and can communicate with smartphones and apps. Therefore, numerous web-based and smartphone apps aim to provide information and various patient data metrics (e.g. caloric intake, activity levels, glucose monitoring) that can be accessed and processed for decision support by smartphone apps. In this narrative review, we highlight current information about the effectiveness of interventions through smartphone apps with a focus on apps designed to give guidance to patients with type 1 diabetes on physical activity monitoring and glucose control during and after structured exercise sessions, as these patients are experiencing huge therapeutic challenges during exercise. Furthermore, we propose a number of critical elements for future apps designed for people with type 1 diabetes.

Keywords: apps, physical activity, smartphones, technology, type 1 diabetes

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Background

Global growth in the use of mobile phones, the so-called smartphones, makes them a powerful platform to provide tailored health monitoring, decision support and education conveniently delivered to patients living with a chronic disease such as diabetes mellitus. Smartphone technologies, and the applications (apps) that they host, are developing rapidly with regard to communication, information processing, design, features and connectivity with other devices (e.g. wearables and health monitors). Diabetes, and in particular type 1 diabetes (T1D), may be particularly suited to smartphone-based support given the challenges around glucose monitoring, insulin dosing, carbohydrate/calorie counting and lifestyle management.[1] Numerous web-based and smartphone apps aim to provide information and various patient data metrics (e.g. caloric intake, activity levels, and glucose monitoring) that can be accessed and processed for decision support by smartphone apps. Modern treatment and monitoring of T1D is also being supported by rapidly evolving technologies such as continuous subcutaneous insulin infusion devices (e.g. pumps), interstitial continuous glucose monitors (CGMs), and Bluetooth-enabled smart pens for insulin delivery tracking and insulin-dosing support using smartphone-based calculators and smart meters that link to an app.

In this narrative review, we highlight current information about the effectiveness of interventions through smartphone apps with a focus on apps designed to give guidance to patients with T1D on physical activity monitoring and glucose control during and after structured exercise sessions.

Methods

During July 2018, the Android (i.e. Google Play Store) and iPhone (i.e. App Store) smartphone app platform stores were searched for content related to exercise and diabetes with an emphasis on content for individuals living with T1D. For this, the terms 'exercise' and 'diabetes' were entered into the search bar of the Android store (~240 apps were initially found) while all 'health and fitness' category apps in the iOS App Store (~600 apps were initially found) were hand searched for relevant content. A total of seven apps were selected from these initial lists that had relevant content on exercise and T1D for this review. A literature search on *PubMed* was also conducted in July 2018 for research studies and reviews on smartphone applications in type 1 diabetes.

Apps and self-management behaviors

A majority of smartphone users download fitness or health apps, and a number of these apps currently available for download are geared to people living with diabetes.[1] T1D is a disease condition that benefits from vigilant self-management around healthy eating, increased physical activity levels, medication adherence and adjustments to insulin dosing. Tracking health data and providing evidence-informed decision support using mobile apps should facilitate improved self- management in T1D. Indeed, a smartphone app that integrates text-message feedback from a certified diabetes education source can lower glycated hemoglobin (HbA1c) levels in adults with T1D who initially have glucose control well above target.[2] Smartphone apps may also assist with reducing the burden of hypoglycemia by improving symptom recognition and pattern recognition.[3] Systematic reviews of available studies examining the effectiveness of interventions with smartphone apps that aim to promote healthy lifestyles (i.e. physical activity, physical fitness, modification of dietary habits, and quality of life) in patients with diabetes show that the use of such apps seems to improve a number of lifestyle factors and helps strengthen the perception of self-care and overall glucose control (e.g. HbA1c and time in a targeted glucose range).[1,4–13] However, as pointed out in a recent systematic review and meta-analysis by Bonoto and colleagues,[14] results to date have severe heterogeneity that may be explained, at least in part, by the levels of healthcare professional (HCP) engagement or consultation with the patient who is using the app. An important distinction is that some apps support HCP engagement/consultation while most others have little or no connection to the healthcare team, at least according to one recent meta-analysis.[15] HCP knowledge about the various apps, awareness of patient engagement with these apps, the limitations of currently available apps and data access are all important considerations for clinical effectiveness. The following section highlights some of the apps that focus on self-care behaviors around physical activity.

Apps and physical activity monitoring and decision support for T1D

Nowadays, there are an increasing number of apps designed to give guidance to patients with T1D during periods of physical activity or exercise combining diabetes-specific information (e.g. glucose levels, insulin and nutrition) with fitness data sources such as step counts, heart rate or caloric expenditure (Table 1). Several challenges exist with exercise management with respect to insulin dose adjustments and carbohydrate feeding to prevent exercise-associated hypoglycemia, insulin corrections for post exercise hyperglycemia, and the management of post exercise, late-onset hypoglycemia.[16] Most young people living with T1D fail to meet the minimum physical activity guidelines,[17] in part because so many barriers exist with glucose control around exercise.[18–21] One recent publication highlights that adults with T1D find it difficult to manage their diabetes and physical activity and that a majority of their decision-making is based on personal trial and error, rather than input from the medical community.[22] While certain websites offer reasonable and somewhat personalized starting points on exercise management for type 1 diabetes (e.g. excarbs.com, runsweet.com, extodorg.ipage.com and jdrf.org/t1d-resources/peak/), a number of newer apps described below aim to make exercise recommendations even more personalized, more portable and with more 'connected' features, such as exercise monitoring with wearables and glucose monitoring with CGMs.

T1Exercise

An app in early release, called T1Exercise (by Syzible Inc. Dublin, Ireland), is an exercise management tool for individuals with T1D who are on multiple daily injections or continuous subcutaneous insulin infusion. This app is developed with expertise from a diabetes center in Dublin, Ireland (Tallaght University Hospital) and uses a consensus decision tree for exercise management.[16] The app provides guidance on 'safe' starting blood glucose levels for exercise and offers insulin dosing and

Table 1. Highlights of some apps that assist with lifestyle management in type 1 diabetes.

Application / website	Diabetes target population	Active coaching function for exercise	Personalized feedback, reminders, logbook	Free version / with costs
T1Exercise (www.syzible.com/)	Type 1	–	+	+/–
DiaBits (www.diabits.com)	Type 1	+	+	+/–
Glucose Buddy (www.glucosebuddy.com)	Type 1 and type 2	–	+	+/–
One Drop (www.onedrop.today)	Type 1 and type 2 (insulin-dependent)	–	+	+/+
Bant (www.bantapp.com)	Type 1	–	+	+/–
MySugr (www.mysugr.com)	Type 1 and type 2	–	+	+/+
GlucoseZone (www.glucosezone.com)	Type 1 and type 2	++	+	+/–

carbohydrate snacking suggestions for a range of planned and unplanned activities. It also logs glucose levels, relative exercise intensity, carbohydrate intake and insulin dosages that are inputted from the user. Data can be exported as pdf or csv files for personal analysis or for consultations with the HCP.

DiaBits

DiaBits (Bio Conscious Tech, Inc. Vancouver, BC, Canada) is a glucose prediction app that integrates CGM data with insulin pump and heart rate data from a wearable device for patients with T1D. The developers proclaim to use machine learning techniques to model glucose behavior based on these parameters and use the information to predict glucose behavior using a patient's physiological state in addition to glucose-insulin dynamics. The app works with the fitness tracker Fitbit (Fitbit Inc., San Francisco, CA, USA) or Apple Watch (Apple Inc., Cupertino, CA, USA). In order to measure the predictive accuracy of this approach, the developers tested the algorithm in cooperation with the British Columbia Children's Hospital in a blinded pilot study. During this study, eight pediatric patients used a CGM and a Fitbit to generate a continuous 60-day patient-specific library of continuous activity, heart rate, and blood glucose data. The data from the first 30 days of the study were used to train a learning algorithm on the effects of different physiological states on blood glucose. The optimized algorithm was used in the following 30 days of the study to predict the user's future glucose values. The 30-min prediction horizon achieved an average accuracy of 83.15% in Zone A and 15.03% in Zone B of a Clarke error grid analysis; the 60-min prediction horizon achieved a 64.36% and 30.56% accuracy, respectively.[23]

Glucose buddy

Glucose Buddy (Azumio Inc. Redwood City, CA, USA) is an app designed for people with T1D and type 2 diabetes. It offers a log of blood glucose levels, carbohydrate intake, medication doses, HbA1c results and exercise. The app offers reminders for checking blood glucose and taking medication. The app can send reports to a HCP *via* the app or website and allows for printable monthly reports to track various trends in glucose, medications and food intake. The app does not currently synchronize with blood glucose meters, CGMs, or insulin pumps.

One Drop diabetes management

One Drop (Informed Data Systems Inc. Austin, TX, USA) is designed for people with T1D and insulin-dependent type 2 diabetes. The app enables manual data entry, but also passive data collection *via* Apple's HealthKit, Apple Watch, Fitbit and the Bluetooth-enabled One Drop Chrome glucose meter. The current app also syncs with Dexcom CGM (G5, G6). It works also with other Bluetooth meters, *via* Apple's Health app. The One Drop mobile app also provides a digital logging wheel for food (with food photo logging) and exercise. A built-in food library expedites carbohydrate tracking, while a medication scheduler reminds users when a dose is due, and tracks doses upon confirmation. The app displays glucose levels, food intake, medications and exercise as color-coded circles on a timeline, with the intent of allowing users to better contextualize these relationships. Statistics of tracked data are viewable on iPhone, Android, and Apple Watch. The app offers a diabetes-related news section and an expert/community support forum. One Drop is free and available on iOS, WatchOS, and Android operating systems. However, One Drop Premium requires the purchase of the One Drop Chrome blood glucose monitoring system.

bant. bant (eHealth Innovation Toronto, Ontario, Canada) is an iPhone-based app designed primarily for young people with T1D that was developed by the University Health Network in collaboration with SickKids Hospital (Toronto, Canada) with input from patients, families, doctors, nurses and engineers. It tracks meals, blood glucose (*via* Bluetooth-enabled LifeScan OneTouch Mini blood glucose meter and Dexcom CGM *via* Apple Health), physical activity, and weight data and provides analytics, personalized feedback and data sharing options with HCPs. The app is named after Dr Frederick Banting who co-discovered insulin in 1921 in Toronto. Trends in glucose are automatically detected by the app and the user can tag possible causes for hypoglycemia and hyperglycemia. The user can then select how they wish to 'tackle' the problem by focusing on changes to medications (i.e. insulin), nutrition or physical activity patterns. Earlier studies showed that bant gamification-like features tended to incentivize young patients to monitor glucose more frequently.[13] A follow-up study of 92 youths showed that increased glucose monitoring with the bant app was associated with a significant improvement in HbA1c in youths with T1D and that the app has a very high satisfaction rating.[12] A current study is examining whether social networking and rewards will encourage and reinforce self-management behaviors in young teens with T1D as they become more independent in their self-management and the next iteration of bant may include features that more easily enable adolescents to receive feedback from caregivers and approaches that integrate the app into routine clinical care.

mySugr

This app, originally developed by mySugr GmbH (Vienna, Austria), now owned by Roche (Basal, Switzerland) and designed for people with T1D and type 2 diabetes. It integrates with CGM systems *via* Apple's Health app and with Medtronic's CareLink data management system. The user is able to log blood glucose, carbohydrate intake, take food photos, log insulin use and gets personalized motivating feedback. The app also generates reports for the HCP. The mySugr Logbook is a registered risk class 1 medical device in the United States and European Union and the mySugr's Bolus Calculator module (currently available for use in Europe) has risk class IIb approval. MySugr does not sync with blood glucose meters but stands for its capacity to maintain app adherence likely because of its interactive gamification-like input features which use challenges and quests.[24,25] To generate health reports as pdfs, one must buy the MySugr PRO version.

GlucoseZone

The GlucoseZone app, developed by Fitscript LLC (New Haven, CT, USA) is a high quality digital designed exercise 'solution' primarily for people with T1D and type 2 diabetes. It provides exercise guidance taking factors like pre-exercise blood glucose levels, medications, and exercise type, into consideration. This app includes four main features: GlucoseZone Today (daily live and interactive workout videos, users can chat live with other online users as well as a workout coach); GlucoseZone Program (a guide to managing diabetes, including lowering HbA1c and weight loss); Live Replay (workouts to do at home, at the gym, or outdoors); and Diabetes Talk (prerecorded videos of certified diabetes professionals discussing topics like heart health, diabetes during the winter, preparing for a successful doctor's visit, and using technology). GlucoseZone recently has developed a partnership with the American Diabetes Association (ADA) to help offer better exercise solutions for people living with diabetes. The exercise videos in GlucoseZone match well with the ADA recommended exercise modalities for all people living with diabetes.[26]

Future considerations for diabetes lifestyle app developments

Based on the mounting success of the above featured apps and others in the subclass of health and fitness, we propose several critical elements for future apps designed for people with T1D:

- Improve comparability issues with Android and iOS smartphones.
- Improve connectivity issues and provide better widespread connectivity with various diabetes-related devices (e.g. CGM, and meters) as well as various exercise wearables that can report on step counts, heart rate and daily energy expenditures.
- Use gamification and reward-based features to help improve app adherence particularly for youths with T1D.
- Provide sound clinical advice on nutrition or insulin dose adjustments strategies *via* interactive selections on the app or *via* instant messaging from Cloud-based support.
- Consider various evidence-informed resources to support the clinical decision-making for exercise management such as the International Society for Pediatric and Adolescent Diabetes Clinical Practice Consensus Guidelines on exercise in children and adolescents.[27]
- Rigorously evaluate the usability, safety and efficacy of these apps in a wide range of patients living with T1D.

With only a few exceptions,[2,12] a majority of the lifestyle management apps developed for patients have not been tested in a large enough clinical population to determine whether glucose control can be improved. We see an urgent need for the scientific evaluation of diabetes health app effectiveness and safety around insulin dose adjustment strategies for exercise. Although there is some indication that the use of diabetes apps can help limit severe episodes of hypoglycemia,[28] current evidence concerning the safety of diabetes apps is scarce. Thus, future long-lasting studies are necessary to further evaluate the effectiveness of these rapidly evolving glucose management apps with direct attention to safety issues, particularly for apps with bolus calculator functionality. Along with this increase in scientific rigor, we advocate for an increased awareness about these apps in physical activity management and for more formalized education of how HCPs can use these apps perhaps more effectively in a select segment of motivated patients.

Author's note

Jointly developed the structure and arguments for the paper: OK, MCR. Wrote the first draft of the manuscript: OK, MCR. Agreed with manuscript content and conclusions: OK, MCR. Made critical revisions and approved final version: OK, MCR. Both authors reviewed and approved of the final manuscript.

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Conflict of interest statement

The authors declare that there is no conflict of interest.

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References

1. Veazie S, Winchell K, Gilbert J, *et al. Mobile applications for self-management of diabetes*. Rockville, MD: Agency for Healthcare Research and Quality, 2018.
2. Kirwan M, Vandelanotte C, Fenning A, *et al.* Diabetes self-management smartphone application for adults with type 1 diabetes: randomized controlled trial. *J Med Internet Res* 2013; 15: e235.
3. Feuerstein-Simon C, Bzdick S, Padmanabhuni A, *et al.* Use of a Smartphone Application to Reduce Hypoglycemia in Type 1 Diabetes: A Pilot Study. *J Diabetes Sci Technol* 2018; 12: 1192–1199.

4. Castensøe-Seidenfaden P, Husted GR, Jensen AK, *et al*. Testing a smartphone app (Young with Diabetes) to improve self-management of diabetes over 12 months: randomized controlled trial. *JMIR mHealth and uHealth* 2018; 6: e141.

5. Torbjørnsen A, Småstuen MC, Jenum AK, *et al*. Acceptability of an mHealth app intervention for persons with type 2 diabetes and its associations with initial self-management: randomized controlled trial. *JMIR mHealth and uHealth* 2018; 6: e125.

6. Lunde P, Nilsson BB, Bergland A, *et al*. The effectiveness of smartphone apps for lifestyle improvement in noncommunicable diseases: systematic review and meta-analyses. *J Med Internet Res* 2018; 20: e162.

7. Arens JH, Hauth W and Weissmann J. Novel app- and web-supported diabetes prevention program to promote weight reduction, physical activity, and a healthier lifestyle: observation of the clinical application. *J Diabetes Sci Technol* 2018; 12: 831–838.

8. Huang Z, Soljak M, Boehm BO, *et al*. Clinical relevance of smartphone apps for diabetes management: a global overview. *Diabetes Metab Res Rev* 2018; 34: e2990.

9. Yom-Tov E, Feraru G, Kozdoba M, *et al*. Encouraging physical activity in patients with diabetes: intervention using a reinforcement learning system. *J Med Internet Res* 2017; 19: e338.

10. Trawley S, Baptista S, Browne JL, *et al*. The use of mobile applications among adults with type 1 and type 2 diabetes: results from the second MILES—Australia (MILES-2) study. *Diabetes Technol Ther* 2017; 19: 730–738.

11. Goyal S and Cafazzo JA. Mobile phone health apps for diabetes management: current evidence and future developments. *QJM* 2013; 106: 1067–1069.

12. Goyal S, Nunn CA, Rotondi M, *et al*. A mobile app for the self-management of type 1 diabetes among adolescents: a randomized controlled trial. *JMIR Mhealth Uhealth* 2017; 5: e82.

13. Cafazzo JA, Casselman M, Hamming N, *et al*. Design of an mHealth app for the self-management of adolescent type 1 diabetes: a pilot study. *J Med Internet Res* 2012; 14: e70.

14. Bonoto BC, de Araújo VE, Godói IP, *et al*. Efficacy of mobile apps to support the care of patients with diabetes mellitus: a systematic review and meta-analysis of randomized controlled trials. *JMIR Mhealth Uhealth* 2017; 5: e4.

15. Hou C, Xu Q, Diao S, *et al*. Mobile phone applications and self-management of diabetes: a systematic review with meta-analysis, meta-regression of 21 randomized trials and GRADE. *Diabetes Obes Metab* 2018; 20: 2009–2013.

16. Riddell MC, Gallen IW, Smart CE, *et al*. Exercise management in type 1 diabetes: a consensus statement. *Lancet Diabetes Endocrinol* 2017; 5: 377–390.

17. Pivovarov JA, Taplin CE and Riddell MC. Current perspectives on physical activity and exercise for youth with diabetes. *Pediatr Diabetes* 2015; 16: 242–255.

18. Brazeau A-S, Rabasa-Lhoret R, Strychar I, *et al*. Barriers to physical activity among patients with type 1 diabetes. *Diabetes Care* 2008; 31: 2108–2109.

19. Lascar N, Kennedy A, Hancock B, *et al*. Attitudes and barriers to exercise in adults with type 1 diabetes (T1DM) and how best to address them: a qualitative study. *PLoS ONE* 2014; 9: e108019.

20. Kennedy A, Narendran P, Andrews RC, Daley A, Greenfield SM; EXTOD Group. Attitudes and barriers to exercise in adults with a recent diagnosis of type 1 diabetes: a qualitative study of participants in the Exercise for Type 1 Diabetes (EXTOD) study. *BMJ Open*. 2018 January 24; 8(1): e017813.

21. Jabbour G, Henderson M and Mathieu M-E. Barriers to active lifestyles in children with type 1 diabetes. *Can J Diabetes* 2016; 40: 170–172.

22. Kime NH, Pringle A, Rivett MJ, *et al*. Physical activity and exercise in adults with type 1 diabetes: understanding their needs using a person-centered approach. *Health Educ Res* 2018; 33: 375–388.

23. Hayeri A. Predicting Future Glucose Fluctuations Using Machine Learning and Wearable Sensor Data. *Diabetes* 2018; 67: 738–P. http://diabetes.diabetesjournals.org/content/67/Supplement_1/738-P

24. Martinez M, Park SB, Maison I, *et al*. iOS App store-based phone apps for diabetes management: potential for use in medication adherence. *JMIR Diabetes* 2017; 2: e12.

25. Miller AS, Cafazzo JA and Seto E. A game plan: gamification design principles in mHealth applications for chronic disease management. *Health Informatics J* 2016; 22: 184–193.

26. Colberg SR, Sigal RJ, Yardley JE, *et al*. Physical activity/exercise and diabetes: a position statement of the American Diabetes Association. *Diabetes Care* 2016; 39: 2065–2079.

27. Adolfsson P, *et al*. ISPAD Clinical Practice Consensus Guidelines 2018: Exercise in children and adolescents with diabetes. *Pediatr Diabetes* 2018; 19(Suppl. 27): 205–226.

28. Thompson B. Do smartphone applications hold the secret to reducing hypoglycemia in type 1 diabetes? *J Diabetes Sci Technol* 2018; 12: 1200–1202.