Title: An evaluation of diabetes targeted apps for Android smartphone in relation to behaviour change techniques

Authors:

Charlotte D Hoppe
School of Food Science and Nutrition
University of Leeds
Leeds LS2 9JT
and
Department of Nutrition and Dietetics
King's College London
Franklin-Wilkins Building
Stamford Street
London SE1 9NH

Janet E Cade
Nutritional Epidemiology Group
School of Food Science and Nutrition
University of Leeds
Leeds LS2 9JT
Phone number: 0113 343 6946
Fax number: 0113 343 2982
E-mail address: j.e.cade@leeds.ac.uk

Michelle Carter
Nutritional Epidemiology Group
School of Food Science and Nutrition
University of Leeds
Leeds LS2 9JT

Keywords: diabetes, behaviour change techniques, mobile apps, Smartphone

Details of role in the study: JEC had the initial idea of the study and had a major role in its design and execution, CDH undertook the evaluation of the apps, the statistical analysis and the majority of drafting the paper and MC contributed to the draft of the paper, reviewed its content and approved the final version for submission.

Abstract

BACKGROUND: Mobile applications (apps) could support diabetes management through dietary, weight and blood glucose self-monitoring; and promoting behaviour change. This study aimed to evaluate diabetes apps for content, functions and behaviour change techniques (BCTs).

METHODS: Diabetes self-management apps for Android smartphones were searched for on Google Play Store. Ten apps each from the following search terms were included; 'diabetes', 'diabetes type 1', 'diabetes type 2', 'gestational diabetes'. Apps were evaluated by being scored according to their number of functions and BCTs, price and user rating.

RESULTS: The average number of functions was 8.9 (SD 5.9) out of a possible maximum of 27. Furthermore, the average number of BCTs was 4.4 (SD 2.6) out of a possible maximum of 26. Apps with optimum BCT had significantly more functions (13.8, 95% CI 11.9, 15.9) than apps that did not (4.7, 95% CI 3.2, 6.2; $p<0.01$) and significantly more BCTs (5.8, 95% CI 4.8, 7.0) than apps without (3.1, 95% CI 2.2, 4.1; $p<0.01$). Additionally, apps with optimum BCT also cost more than other apps. In the adjusted models, highly rated apps had an average of 4.8 (95% CI 0.9, 8.7; $p=0.02$) more functions than lower rated apps.

CONCLUSION: 'Diabetes apps' include few functions or BCTs compared to the maximum score possible. Apps with optimum BCTs could indicate higher quality. App developers should consider including both specific functions and BCTs in 'diabetes apps' to make them more helpful. More research is needed to understand components of an effective app for people with diabetes.

Introduction

Diabetes mellitus is becoming increasingly prevalent worldwide. Currently, 387 million people are diagnosed with diabetes, representing 8.3% of the global population[(1)], and this figure is expected to rise to 592 million by the year 2035. Affected individuals have to manage it for the rest of their lives. A number of long term complications are associated with diabetes[(2)], and effective control of blood pressure and blood glucose reduces the risk of both macro-vascular and micro-vascular diseases[(3; 4; 5)]. It is therefore important to carefully manage the disease to minimise its impact on morbidity and mortality.

In 2015, 76% of the UK population owned a Smartphone[6], and it is predicted that by 2017, 2.5 billion people worldwide will own a Smartphone [7]. Smartphones therefore have the potential to be used to manage disease using "mHealth" (mobile health) applications[8]. There were over 6,000 medical apps available on the Android market in 2013[9], and this has since nearly quadrupled to 23,000 apps[10]. Many apps aim to support self-management for people with diabetes, however, while mHealth apps may benefit people suffering from chronic disease, there are also problems associated with them. These problems include lack of evidence on clinical effectiveness, lack of integration into the health care system and potential threats to safety [9]. A recent study found that health apps in the UK NHS Health Apps Library had poor compliance with data protection principles[11]. For an app to be recommended to patients by health professionals, its effectiveness should be scientifically proven. Most apps do not have a strong evidence base demonstrating their effectiveness. The US Food and Drug Administration (FDA) defined a mobile app to be a medical device if it was intended to diagnose, cure, mitigate, treat or prevent a disease[12], needing FDA approval before being released to the market. Unapproved apps could lead to adverse health effects if users substituted a doctor's visit with consulting an app[9].

There is substantial research investigating new technology in the use of managing disease. However, in relation to diabetes-linked conditions, these are mostly focused on weight loss, and look at web-based programmes rather than mobile apps[13; 14]. Additionally, these studies have not looked at BCTs, but rather measure BMI (Body Mass Index, kg/m^2) or body weight as outcomes. While these are appropriate outcomes to measure effectiveness of diabetes management interventions, it is also important to understand which BCTs are promoting effective behaviour change. Some diabetes management apps have been evaluated, but these were web-based rather than mobile app-based[16; 17], and measure user satisfaction or usability[18; 19] rather than BCTs. A qualitative study on usability of apps for weight loss[20] concluded that app designers should employ BCTs to improve effectiveness. Furthermore, a Cochrane review[21] investigated which computer-based intervention would be most effective at improving HbA1c levels in adults with diabetes, and found that mobile apps were more effective than computer programmes used in hospitals or at home. The authors thought that this was due to the inclusion of control theory techniques such as self-regulation.

Twenty six distinct, theory-linked BCTs have been described and tested[22]. BCTs are theory-based methods to facilitate change in individuals, and examples include 'Prompt intention formation' and 'Model or demonstrate behaviour' which could be incorporated into mobile apps. A meta-analysis[23] was undertaken to assess the effectiveness of these 26 BCTs in promoting physical activity and healthy eating. It found that interventions that combined self-monitoring with at least one other technique derived from control theory were significantly more effective than the other interventions. The aim of this study was to evaluate Android apps for people with diabetes in terms of which functions they included and which BCTs they employed to encourage behaviour change. To our knowledge there is no research assessing the inclusion of BCTs in interventions used in diabetes mobile apps. This research could provide a basis for improving 'diabetes apps' in the future.

Methods

App selection

Google Play Store (UK) for Android was used as a database to search for relevant apps on 27 October 2014. Since there is no existing appropriate category, these specific search terms were used: 'diabetes', 'diabetes type 1', 'diabetes type 2' and 'gestational diabetes'. The apps were initially pre-screened for suitability before being downloaded. Inclusion criteria were 1) to be intended for patients with type 1, 2 or gestational diabetes, 2) to be addressing any aspect of management of diabetes (e.g. blood glucose monitoring, medication, healthy diet), 3) to have stand-alone functionality (i.e. not requiring membership in a specific programme or website to function) and 4) to be in English. The exclusion criteria were 1) to be for self-diagnosis for the user and 2) to be intended for education of medical personnel. Apps that did not function properly on the test phone, for example, they would not open or we could not get past the introduction screen, were also excluded. This pre-screening was based on the app descriptions and screenshots provided in Google Play Store. The number of medical apps available on Google Play Store is 23,000[(10)] with only a small proportion of these of relevance to people with diabetes . The exact number of 'diabetes apps' could not be determined as Google Play Store does not state the number of search results. Each search only shows 200 app results. Due to restraints in time and resources, the number of apps included had to be restricted. The first ten apps passing the pre-screening from each search term were included, giving 40 apps in total. App ranking is partly determined by App Store Optimisation, which among other aspects takes into account keyword alignment (i.e. how the user's search term matches with words in the app title and description), and app performance (e.g. app ratings and number of downloads)[(24)]. An algorithm is used to determine the exact ranking, and this is not available to the general public, and undergoes continuous change[(25)]. For the purposes of this study it is therefore not possible to find out the total number and ranking of all available diabetes-related apps.

Following identification, the apps were downloaded and evaluated again based on the same inclusion and exclusion criteria as stated above. At this point some of the apps were excluded, and therefore a second stage of searches and screening was performed to meet the study's aim of evaluating 40 apps, ten from each search term (**Figure 1**). This second search was performed on 9 June 2015. Five apps were independently evaluated by another assessor in order to determine the repeatability and relative validity of the assessments.

App testing

Each app that met the inclusion and exclusion criteria was used by the author (CH) to identify the functions and BCTs included. The results were recorded in a data extraction form (**Table 4**) recording the functions and BCTs included in each app. A possible 27 functions were categorised into 'Provision of information', 'Allows self-recording', 'Generates output from self-recording', 'Data management' and 'Other'. The 26 BCTs identified by Michie and Abraham[22], were categorised into 'Motivation enhancing', 'Planning and preparation' and 'Goal striving and persistence' (see a list of these in **Figures 2-3**). Therefore, a maximum score of 53 could be obtained by each app. Each app was downloaded immediately before assessment using the author's private mobile phone. The majority of apps were evaluated between the 3 November and 10 December 2014, and apps identified in the second search stage were evaluated between the 9 June and 15 June 2015. Some apps had data collection functions, such as recording blood glucose readings or food intake, and where this was the case, they were used for two days to give sufficient data for graph generation. Apps which did not have data collection functions were explored to extract information on all other functions and BCTs present.

Based on the meta-analysis by Michie et al. found [23], the most effective combination of BCTs is 'Prompt self-monitoring of behaviour' in combination with at least one of four other self-regulatory techniques: 'Prompt intention formation', 'Prompt specific goal setting', 'Provide feedback on performance' and 'Prompt review of behavioural goals'. This was evaluated as 'optimum BCT' in this study'.

Statistical analysis

The results were analysed using the statistical software Stata/IC (Release 13.1; Stata Corp, College Station, TX). T-tests were performed to assess the difference in mean number of functions, number of BCTs, overall score, price and user rating according to inclusion of 'optimum BCT', price (free or paid) and user rating. For the latter, user rating, normally ranging from one to five, was divided into the following two groups; low=1.0-4.0 and high=4.1-5.0. The uneven division of user rating was due to average app rating for the majority of apps being greater than 4. Regression was performed to see if there was a relationship between number of functions, number of BCTs and overall score versus price (£) and user rating. Regression models for price adjusted for user rating and vice versa. Cohen's kappa was calculated to determine the inter-rater reliability from the duplicate extracted data.

Results

App selection

The initial pre-screening gave a list of 40 apps to be further evaluated for eligibility. Of these, 13 apps were excluded due to non-conformity with inclusion criteria (**Figure 1**). The excluded apps were either intended for training of health personnel (n=2), no longer available at the point of download (n=5), required the use of a website along with the app (n=2), non-functional (n=1), not in English (n=1) or not for previously diagnosed patients (n=2). This initially gave 27 apps to be included in the study. However, to improve the generalisability of the study, 13 further apps were added from a repeated search to give 40 apps in total. These were individually pre-screened before inclusion.

App testing

Based on overall score (i.e. the sum of number of functions and BCTs), Diabetes Tracker by Mig Super, Diabetes:M by Rossen Varbanov and Diabetes Companion by mySugr GmbH ranked highest, scoring 29, 27 and 26 out of 53 respectively. These were all apps that offered recording of various physical measures, e.g. blood glucose, weight and height. They all included 'optimum BCT'. The apps scoring lowest overall were Type 1 Diabetes by Colby Taylor, Recipes for Diabetes by University of Illinois Extension and Diabetic Diet Samples by Awesomeappcenter LLC, with scores of 2, 3 and 4 and out of 53 respectively. These apps focused on giving information and advice about the disease and how to manage it. The average overall score was 13.2 (standard deviation (SD) 7.4) out of 53 (**Table 3**).

The average number of functions included in the apps was 8.9 (SD 5.9) out of 27 (**Table 3**). The most common functions were 'Enter blood glucose values' and 'Export data to Smartphone/send data', which were included in 23 and 22 of the apps respectively. This involved downloading data or graphs to the Smartphone directly; sending it to a specified email address; or uploading it to a cloud based storage system. Other common functions included enter medication; weight; carbohydrates consumed. Thirty-two out of the 40 apps included 'Any other (describe)', a mixed group of functions including anything that was not included in the rest of the list. These ranged from offering a forum to communicate with other people with diabetes; a game including a point system for doing beneficial activity; making a shopping list for meals; and information on which McDonald's meals were 'diabetic-friendly', and few were found in more than one app. Only one app included the potential to generate a table of nutrients consumed. None of the apps included ‘Technological additional feature: Connect glucose meter to Smartphone to transfer data’ (**Figure 2**).

The inclusion of BCTs in apps was far less common than the inclusion of functions. The average number of BCTs was 4.4 (SD 2.7) out of 26 (**Table 3**). The most commonly included technique was ‘Prompt self-monitoring of behaviour’ (n=23) and ‘Prompt intention formation’ (n=20). These techniques are both among the self-regulatory techniques which were identified as most effective when used in combination with each other[(23)]. However, fewer apps (n=18) had ‘optimum BCT’ defined as ‘Prompt self-monitoring of behaviour’ with at least one other self-regulatory technique (i.e. ‘optimum BCT’ ‘Prompt intention formation’, ‘Prompt specific goal setting’, ‘Provide feedback on performance’ and ‘Prompt review of behavioural goals’). Five BCTs were not used in any of the apps: ‘Prompt barrier identification’, ‘Agree on behavioural contract’, ‘Prompt practice’, ‘Prompt self-talk’, and ‘Motivational interviewing’ (**Figure 3**).

App characteristics

Apps including ‘optimum BCT’ had more functions (13.8, 95% CI 11.9, 15.9) than apps that did not (4.7, 95% CI 3.2, 6.2; p<0.01). This was also true in all the subgroups of functions. The same was found to be true with regard to the BCTs themselves, with more BCTs (5.8, 95% CI 4.8, 7.0) in apps with ‘optimum BCT’ than in apps without (3.1, 95% CI 2.2, 4.1; p<0.01). Logically, apps with ‘optimum BCT’ also had an overall higher score (19.8, 95% CI 17.1, 22.5) than those that did not have ‘optimum BCT’ (7.9, 95% CI 6.3, 9.4; p<0.01). Furthermore, apps with ‘optimum BCT’ had a higher price (in £) (3.2, 95% CI 0.6, 5.9) than those without (0.3, 95% CI -0.0, 0.5; p=0.01) (**Table 1**).

Apps with a high user rating had more functions (10.6, 95% CI 8.3, 13.9) than those that had a low rating (6.2, 3.0, 9.5; p=0.03). This was also true for the functions subgroups, except ‘Other’. Conversely, the number of BCTs included was not related to user rating (high user rating number of BCTs 4.5, 95% CI 2.8, 6.1) vs. (low user rating number of BCTs 4.5, 95% CI 3.6, 5.3; p=0.98). Only BCTs in the subgroup ‘Goal striving and persistence’ were significantly more common in highly rated apps (2.7, 95% CI 2.0, 3.4) compared to low user rated apps (1.5, 95% CI 0.4, 2.6; p=0.05). However, there was an indication of a higher user rating in apps with ‘optimum BCT’ (4.4, 95% CI 4.2, 4.5) than in those without (4.0, 95% CI 3.6, 4.4; p=0.07) (**Table 1**).

The regression analysis also resulted in a significant association between number of functions, but not BCTs, and user rating (**Table 2**). In the adjusted models, highly rated apps had an average of 4.8 (95% CI 0.9, 8.7; p=0.02) more functions than lower rated apps. However, payment for an app was significantly related to higher number of BCTs; paid apps had a higher number of BCTs by 1.9 (95% CI 0.1, 3.8; p=0.04) than free ones. Price did not affect the overall score, but user rating was associated with overall score. Highly rated apps had a higher overall score by 5.1 (95% CI 0.1, 10.0; p=0.04).

The inter-rater reliability gave an average agreement of 86% and kappa was 0.68, corresponding to a substantial or good agreement between raters.

Discussion

The inclusion of 'optimum BCT' has been used as a proxy for app quality, because this combination of BCTs is most effective at changing behaviour[23] and is therefore potentially most beneficial to a person with diabetes using the app. The analysis showed that both the number of functions and the number of BCTs included in the apps were quite low. The average number of BCTs was only 4.4 (SD 2.6) out of 26. Therefore, BCTs were probably not actively considered in the development of the apps. Diabetes is a chronic disease requiring lifelong management; changing behaviour is key to achieving this successfully[26]. The combination of BCTs that was found to be most effective[23], was only included in 18 of the 40 apps. It is clear that there is still considerable potential for improvement of BCT inclusion in 'diabetes apps'.

Apps with optimum BCT had significantly more functions and BCTs, indicating that these could be predictors of app quality. Furthermore, user rating significantly predicted the number of functions included; whereas price was linked to increased number of BCTs. There was a non-statistically significant suggestion of a higher user rating in apps with 'optimum BCT' compared to apps without the optimum combination of BCTs. The validity of user rating as a predictor of app effectiveness is uncertain, as most users are unlikely to base their rating on whether they managed to change behaviour. Research on user reviews[27] found that the most common causes of complaint were among others attractiveness, stability and compatibility. None of the causes listed were related to the apps' ability to change behaviour. Apps with 'Optimum BCT' cost more than others. West et al.[29], who appraised a number of apps based on their potential to influence behaviour change found that more expensive apps were more likely to be scored as intending to promote health or prevent disease.

The small sample size of the study, only 40 apps were evaluated, could have limited our ability to determine predictors of app quality. With approximately 23,000[10] health apps available, the total number of 'diabetes apps' is likely to be much greater than 40 and the sample size therefore presents a limitation to this study. Additionally, iTunes Store was not searched for apps, and there is a possibility that there are some key diabetes management apps which were therefore missed. We did however undertake independent evaluation of a subsample of the apps included and found good agreement between reviewers. Resource implications precluded duplicate extraction of all apps, which is another limitation of this study.

Diabetes Tracker by Mig Super, which scored highest in this study, is an app that includes recording of blood glucose, carbohydrate consumption and activity, as well as providing tips for recipes and physical exercises, dietary guidelines for each type of diabetes and information on so-called 'superfoods'. The app that scored lowest, Type 1 Diabetes by Colby Taylor included different types of functions. They were more informative and advisory; giving rather limited information about the condition and about healthy meals that could keep blood sugar levels stable. It is clear that apps directed at people with diabetes include a range of different functions, making comparisons between them challenging. This variation in intended use creates a heterogeneity which might impact on the results.

As previously mentioned, there were five BCTs that were not included in any app. It might be unrealistic to think that all of the BCTs can feasibly be fitted into a mobile phone app. Some techniques would be more challenging to include since there was no link to a human decision maker, e.g. deciding when the target behaviour has been reached, or if the participant has relapsed. Peer or health care professional support would be possible through links to social media or downloads to surgery records. 'Agree on behavioural contract' could have been included in an app, for instance as behavioural goals written by the user themselves within the app or for the user to agree to pre-written goals.

The function 'Connect glucose meter to Smartphone to transfer data' was not included in any apps. The list of possible functions was developed by the author, partly based on similar research done by Chen[30] as well as knowledge about which elements are important when managing diabetes. However, expecting the inclusion of this function is not unreasonable. There are 'diabetes apps' currently on the market, not identified by our search which do have the possibility of being connected to a blood glucose meter either via a USB cable (e.g. Apps Glooko by Glooko and iBGstar by Sanofi

Diabetes) or wirelessly via Bluetooth (e.g. iHealth Gluco-Smart by iHealth Lab Inc.), and thereby transferring glucose readings directly to the diabetes management app. This is a great advantage to the user because it eliminates the burden of manually entering blood glucose values into the app.

As briefly mentioned previously, one app included a game where the user could earn points for undertaking health behaviours (Diabetes Companion by mySugr GmbH). Gamification is a term describing the use of game elements in a non-game setting[(31)]. There is some evidence that gamification is useful in the management of diabetes[(31; 32)], and Diabetes Companion is also one of the highest scoring apps in this study, possibly due to greater facilitation of some BCTs. Similarly, social support has repeatedly been shown to have a beneficial effect on diabetes management[(33),(34)], but only nine out of the 40 apps provided at forum for the users to communicate among each other ('Link to social media'). Again, this aspect could be worth including in a 'diabetes app' in order to improve outcomes for the user.

A weakness of this study is that it did not measure actual behaviour change as an outcome. Instead, the inclusion of specific BCTs was used as a proxy for effectiveness[(23)]. The optimum BCT score was derived from a peer reviewed meta-analysis including 122 papers. Although this was not focussed on diabetes management, but on diet and physical activity, these are both factors important in the management of type 2 diabetes. More recent evidence, published after the main part of the present study was conducted is conflicting. Avery et al. conducted a meta-analysis to determine which BCTs were most effective at increasing levels of physical activity, and consequently improving HbA1c levels in adults with diabetes type 2[(35)]. The four most effective techniques they found were 'Prompt focus on past success', 'Barrier identification/problem-solving', 'Use of follow-up prompts' and 'Provide information on where and when to perform physical activity'. 'Prompt focus on past success could be perceived as included within 'self-monitoring of behaviour' provided that this behaviour was indeed a success. Apart from that, the techniques found to be most effective differed completely. This suggests that finding BCTs that can be generalised to behaviour change interventions is difficult and may be behaviour or condition specific. Future work may include different interpretations of the most effective BCTs or undertaking a randomised controlled trial of apps including measurement of behaviour change as an outcome.

The aim of this study was to evaluate 'diabetes apps' with regard to behaviour change techniques. The same taxonomy of BCTs has previously been used in relation to mobile apps for physical activity and diet[(36)]. However, we believe this is the first study looking at BCTs in 'diabetes apps'. The mobile app market is quickly changing and can be perceived as rather chaotic[(37)]. Health apps that have not been approved by a professional body may be problematic if users are not instructed correctly. The European Directory of Health Apps (2012) reviewed about 200 health apps in cooperation with patient groups[38]. The 'diabetes apps' included that overlapped with the apps evaluated here were Carbs & Cals by Chello Publishing, Diabetes UK Tracker by Diabetes UK, Glucose Buddy by Azumio, Inc. and OnTrack Diabetes by Medivo. The Directory did not quantitatively evaluate the apps; included apps were recommended by patient groups. These four apps ranked within the upper half of the apps evaluated in the present study. Demidowich et al. assessed 42 'diabetes apps' in 2011[19], though they did not include BCTs. Their highest ranking apps were Glucool Diabetes, OnTrack Diabetes, Dbees and Track3 Diabetes Planner. This agrees with the results from the present study which also evaluated Glucool Diabetes by 3qubits and OnTrack Diabetes by Medivo, ranking them seventh and eighth overall.

In conclusion, we have conducted a study evaluating diabetes self-management apps with regard to BCTs. This is highly relevant in today's society as both Smartphone usage and diabetes is becoming increasingly prevalent. Behaviour change is an essential aspect of successful diabetes management, and incorporating BCTs in 'diabetes apps' is a great opportunity to provide people with diabetes with a self-management tool. However, the 'diabetes apps' on the Android market were found to generally include few functions and even fewer BCTs. The three apps scoring most highly in this study were Diabetes Tracker by Mig Super, Diabetes:M by Rossen Varbanov and Diabetes Companion by mySugr GmbH, these had the most functions and BCTs and including the combination of BCTs thought to be most effective at changing behaviour. Health professionals may want to recommend these apps to people with diabetes. More research on the effectiveness of BCTs in mobile apps is needed, this time with more tangible outcomes of behaviour change techniques, for instance HbA1c levels or weight change. With effectiveness established, app developers could work in conjunction with doctors, dietitians and psychologists, who have expert knowledge in the field, to include more BCTs in apps and make them as beneficial to the patients as possible.

Acknowledgements

The authors acknowledge the support from Marion Hery in the duplicate evaluation of the apps.

Conflict of interest

This work was carried out without external funding and no competing financial interests exist. JEC and MC have developed a smartphone app My Meal Mate which aims to support weight loss.

References

1. International Diabetes Federation (2014) IDF DIABETES ATLAS.
2. van Dieren S, Beulens JWJ, van der Schouw YT et al. (2010) The global burden of diabetes and its complications: an emerging pandemic. European Journal of Cardiovascular Prevention & Rehabilitation **17**, s3-s8.
3. Gaede P, Lund-Andersen H, Parving HH et al. (2008) Effect of a multifactorial intervention on mortality in type 2 diabetes. New England Journal of Medicine **358**, 580-591.
4. Lyakishev AA (2006) Intensive diabetes treatment and cardiovascular disease in patients with type 1 diabetes. Results of the DCCT/EDIC study. Kardiologiya **46**, 73-73.
5. AA (1998) Tight blood pressure control and risk of macrovascular and microvascular complications in type 2 diabetes: UKPDS 38. British Medical Journal **317**, 703-713.
6. Deloitte (2015) Mobile Consumer 2015: The UK cut. http://www.deloitte.co.uk/mobileuk/
7. EMarketer (2014) 2 Billion Consumers Worldwide to Get Smart(phones).
8. World Health Organisation (2011) mHealth: New horizons for health through mobile technologies.
9. Eng DS, Lee JM (2013) The Promise and Peril of Mobile Health Applications for Diabetes and Endocrinology. Pediatr Diabetes **14**, 231-238.
10. AppBrain (2015) Most popular Google Play categories.
11. Huckvale K, Prieto JT, Tilney M et al. (2015) Unaddressed privacy risks in accredited health and wellness apps: a cross-sectional systematic assessment. BMC Medicine **13**, 1-13.
12. US Food and Drug Administration (2015) Mobile Medical Applications - Guidance for Industry and Food and Drug Administration Staff.
13. Harvey-Berino J, Pintauro S, Buzzell P et al. (2002) Does using the Internet facilitate the maintenance of weight loss? International Journal of Obesity **26**, 1254-1260.
14. Aguilar-Martínez A, Solé-Sedeño JM, Mancebo-Moreno G et al. (2014) Use of mobile phones as a tool for weight loss: a systematic review. Journal of Telemedicine and Telecare **20**, 339-349.
15. Jeffery RW, Epstein LH, Wilson GT et al. (2000) Long-term maintenance of weight loss: Current status. Health Psychology **19**, 5-16.
16. McKay H, Feil, E., Glasgow, R. & Brown, J. (1998) Feasibility and Use of an Internet Support Service for Diabetes Self-Management. The Diabetes Educator **24**, 174-179.
17. Balas EA, Krishna S, Kretschmer RA et al. (2004) Computerized knowledge management in diabetes care. Medical Care **42**, 610-621.
18. Bain TM, Jones ML, O'Brian CA et al. (2015) Feasibility of smartphone-delivered diabetes self-management education and training in an underserved urban population of adults. Journal of Telemedicine and Telecare **21**, 58-60.
19. Demidowich AP, Lu K, Tamler R et al. (2012) An evaluation of diabetes self-management applications for Android smartphones. Journal of Telemedicine and Telecare **18**, 235-238.
20. Tang J, Abraham C, Stamp E et al. (2015) How can weight-loss app designers' best engage and support users? A qualitative investigation. British Journal of Health Psychology **20**, 151-171.
21. Pal K ES, Michie S, Farmer AJ, Barnard ML, Peacock R, Wood B, Inniss JD, Murray E. (2013) Computer-based diabetes self-management interventions for adults with type 2 diabetes mellitus. Cochrane Database of Systematic Reviews.
22. Abraham C, Michie S (2008) A taxonomy of behavior change techniques used in interventions. Health Psychology **27**, 379-387.
23. Michie S, Abraham C, Whittington C et al. (2009) Effective techniques in healthy eating and physical activity interventions: A meta-regression. Health Psychology **28**, 690-701.
24. Briggs J (2015) Everything You Need to Know About Mobile App Search. In Moz, vol. 2015.
25. Gauchet S (2013) OPTIMIZE YOUR GOOGLE PLAY STORE APP DETAILS PAGE. In apptamin.
26. Peyrot M, Rubin RR (2007) Behavioral and Psychosocial Interventions in Diabetes: A conceptual review. Diabetes Care **30**, 2433-2440.
27. Fu B, Lin J, Li L et al. (2013) Why people hate your app: making sense of user feedback in a mobile app store. In Proceedings of the 19th ACM SIGKDD international conference on Knowledge discovery and data mining, pp. 1276-1284. Chicago, Illinois, USA: ACM.
28. Pagano D, Maalej W (2013) User feedback in the appstore: An empirical study. In Requirements Engineering Conference (RE), 2013 21st IEEE International, pp. 125-134.
29. West JH HP, Hanson CL, Barnes MD, Giraud-Carrier C, Barrett J (2012) There's an App for That: Content Analysis of Paid Health and Fitness Apps. J Med Internet Res **14**, e72.
30. Chen J CJ, Allman-Farinelli M (2015) The Most Popular Smartphone Apps for Weight Loss: A Quality Assessment. JMIR mHealth uHealth **3**, e104.
31. Cugelman B (2013) Gamification: What It Is and Why It Matters to Digital Health Behavior Change Developers. JMIR Serious Games **1**, e3.
32. Kamel Boulos MN, Gammon, S., Dixon, M. C., MacRury, S. M., Fergusson, M. J., Miranda Rodrigues, F., Mourinho Baptista, T., Yang, S. P. (2015) Digital Games for Type 1 and Type 2 Diabetes: Underpinning Theory With Three Illustrative Examples. JMIR Serious Games **3**, e3.
33. Toma T, Athanasiou T, Harling L et al. (2014) Online social networking services in the management of patients with diabetes mellitus: Systematic review and meta-analysis of randomised controlled trials. Diabetes Research and Clinical Practice **106**, 200-211.
34. van Dam HA, van der Horst FG, Knoops L et al. (2005) Social support in diabetes: a systematic review of controlled intervention studies. Patient Education and Counseling **59**, 1-12.
35. Avery L, Flynn D, Dombrowski SU et al. (2015) Successful behavioural strategies to increase physical activity and improve glucose control in adults with Type 2 diabetes. Diabetic Medicine, n/a-n/a.
36. Brannon EE, Cushing CC (2014) Is There an App for That? Translational Science of Pediatric Behavior Change for Physical Activity and Dietary Interventions: A Systematic Review. Journal of Pediatric Psychology.

37. Nass I (2015) The Mobile App Market Is Changing In 2015, Try And Keep Up. In Dazeinfo, vol. 2015.
38. European Commission (2012-2013) European Directory of Health Apps 2012-2013: A review by patient groups and empowered consumers. London: PatientView.

The mobile applications

1. 3qubits. 2013. Glucool Diabetes (Premium) (1.4.3.1). [mobile app]. [Date accessed: 06.12.2014]
2. Apps Den. 2014. Gestational Diabetes (1.0). [mobile app]. [Date accessed: 07.12.2014]
3. Avinash Kulkarni. 2012. Diabetes Guide (1.0). [mobile app]. [Date accessed: 10.12.2014]
4. Awesomeappcenter LLC. 2013. Diabetic Diet Samples (1.0). [mobile app]. [Date accessed: 26.11.2014]
5. Azumio, Inc. 2012. Glucose Buddy: Diabetes Log (1.0). [mobile app]. [Date accessed: 06.11.2014]
6. Colby Taylor. 2012. Type 1 Diabetes (1.0). [mobile app]. [Date accessed: 19.11.2014]
7. Chello Publishing Limited. 2014. Carbs & Cals – Diabetes & Diet (2.11). [mobile app]. [Date accessed: 12.06.2015]
8. David Froehlich. 2012. DiaLog: Diabetes Logbook (1.3.12). [mobile app]. [Date accessed: 10.06.2015]
9. Dheryta. 2013. T1DM – Manage Type 1 Diabetes (3.0). [mobile app]. [Date accessed: 20.11.2014]
10. Diabetes Digital Media Ltd. 2015. Diabetes PA (Diabetes Manager) (1.1.0). [mobile app]. [Date accessed: 11.06.2015]
11. Diabetes Digital Media Ltd. 2014. Diabetes Forum (3.11.34). [mobile app]. [Date accessed: 26.11.2014]
12. Diabetes UK. 2013. Diabetes UK Tracker (1.4). [mobile app]. [Date accessed: 19.11.2014]
13. EasyMobileApp. 2014. Easy Diabetes (1.7.0). [mobile app]. [Date accessed: 26.11.2014]
14. Gordon Wong. 2015. BG Monitor Diabetes Pro (6.8.4). [mobile app]. [Date accessed: 12.06.2015]
15. Gtxcel. 2014. Diabetes Forecast® (4.41). [mobile app]. [Date accessed: 11.6.2015]
16. Heyworld.dk. 2014. Pregnant with diabetes (1.1.0). [mobile app]. [Date accessed: 10.12.2014]
17. Jeschua Schang. Diabetes Diary (1.2.2). [mobile app]. [Date accessed: 12.06.2015]
18. Klimaszewski Szymon. 2014. Diabetes – Glucose Diary (1.3.04). [mobile app]. [Date accessed: 16.11.2014]
19. KoolAppz. 2011. Diabetes Type 2 Guide (1.0). [mobile app]. [Date accessed: 20.11.2014]

20. LISIERE MEDIA LLC. 2013. Diabetic Grocery List (2.1). [mobile app]. [Date accessed: 26.11.2014]
21. Medhelp, Inc – Top Health Apps. 2014. Sugar Sense – Diabetes App (1.0.1). [mobile app]. [Date accessed: 06.12.2014]
22. Medivo. 2014. OnTrack Diabetes (3.2.5). [mobile app]. [Date accessed: 03.11.2014]
23. Mig Super. 2014. Diabetes Tracker (1.8). [mobile app]. [Date accessed: 09.06.2015]
24. moveforward. 2012. Diabetes Forum for Diabetics (1.3.18). [mobile app]. [Date accessed: 15.06.2015]
25. mySugr GmbH. 2014. Diabetes Companion (2.3.4). [mobile app]. [Date accessed: 13.11.2014]
26. Naster Solomon. 2014. Gestational Diabetes (1.0). [mobile app]. [Date accessed: 08.12.2014]
27. NetSummitApps. 2015. Diabetic Recipes! (1.2). [mobile app]. [Date accessed: 12.06.2015]
28. Personal Remedies. 2014. Diabetes Type 2 (1.0). [mobile app]. [Date accessed: 20.11.2014]
29. Peter Wescott. 2011. Diabetic Assistant (2.0). [mobile app]. [Date accessed: 11.06.2015]
30. Riafy Technologies. 2014. Diabetes Recipes Free (7.0.0). [mobile app]. [Date accessed: 11.11.2014]
31. Rossen Varbanov. 2015. Diabetes:M (3.0.2). [mobile app]. [Date accessed: 09.06.2015]
32. Rossen Varbanov. 2014. My Diabetes (2.3.5). [mobile app]. [Date accessed: 12.11.2014]
33. SINIVO Ltd. & Co KG. 2014. SiDiary Diabetes Management (1.27). [mobile app]. [Date accessed: 28.11.2014]
34. Social Diabetes. 2014. Social Diabetes (2.8.4). [mobile app]. [Date accessed: 03.11.2014]
35. SquareMed Software GmbH. 2014. Diabetes Connect (2.0.2). [mobile app]. [Date accessed: 19.11.2014]
36. SquareMed Software GmbH. 2014. Diabetes Plus (1.0.4). [mobile app]. [Date accessed: 16.11.2014]
37. Suderman Solutions. 2014. Diabetes Journal (1.4.4). [mobile app]. [Date accessed: 11.11.2014]
38. TopAppsFor-Health. 2014. Diabetes Tools – Glucose (1.2). [mobile app]. [Date accessed: 10.12.2014]
39. Twayesh Projects. 2014. AudioBook – Diabetes (26.0). [mobile app]. [Date accessed: 10.06.2015]
40. University of Illinois Extension. 2013. Recipes for Diabetes (1.1). [mobile app]. [Date accessed: 11.06.2015]