Mobile applications for adolescents with type 1 diabetes *mellitus*: integrative literature review

Aplicativos para adolescentes com diabetes *mellitus* tipo 1: revisão integrativa da literatura

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Descritores
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Abstract

Objective: To examine the functionalities of mobile applications for self-care of adolescents with type 1 diabetes *mellitus*.

Methods: Integrative review targeting articles in journals indexed in the following databases: Cumulative Index to Nursing and Allied Health Literature, Cochrane Library, Latin American Health Sciences Literature, PubMed (National Library of Medicine), Scopus, and Web of Science in the period between 2012 and 2017 using the following descriptors and their respective descriptors in English and Spanish: mobile applications, self-care and type 1diabetes *mellitus*.

Results: Databank query yielded 248 articles, out of which 12 articles met the selection criteria and were included in the final analysis. Applications were examined in terms of functionalities catering for glycemic control, insulin therapy, diet, physical activity, sentiment analysis and social relationships. No article reported on an application featuring all of the examined functionalities.

Conclusion: Mobile application functionalities were pointed out as essential aids in glycemic control of adolescents with type 1 diabetes *mellitus*.

Resumo

Objetivo: Examinar os recursos de aplicativos para dispositivos móveis destinados ao autocuidado de adolescentes com diabetes *mellitus* tipo 1.

Métodos: Revisão integrativa por meio da busca de artigos nos periódicos indexados nas bases de dados: *Cumulative Index to Nursing and Allied Health Literature, Cochrane Library*, Literatura Latino-Americana em Ciências da Saúde, *PubMed* (*National Library of Medicine*), *Scopus*, e *Web of Science* no período de 2012 a 2017, utilizando os seguintes descritores: aplicativos móveis, autocuidado e diabetes *mellitus* tipo 1, bem como respectivos descritores em inglês e espanhol.

Resultados: A busca gerou um total de 248 artigos, dos quais 12 artigos atenderam os critérios de seleção. Os recursos dos aplicativos foram examinados a partir das funções de controle glicêmico, insulinoterapia, alimentação, atividade física, abordagem dos sentimentos e relações sociais. Observou-se que nenhum artigo descreveu um aplicativo que integrasse todos os recursos examinados.

Conclusão: Os recursos de aplicativos para dispositivos móveis foram apontados como necessários para auxiliar no controle glicêmico de adolescentes com diabetes *mellitus* tipo 1.

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Introduction

The worldwide incidence of type 1 diabetes mellitus in adolescents is 0.5 new cases/100,000 individuals per year. among the countries with the highest number of cases, Brazil ranks third (5,000) after the United States (13,000) and India (10,900).[1] Inadequate control has been linked to short-term consequences such as hypoglycemia, hyperglycemia and diabetic ketoacidosis, and to long-term consequences such as limb amputation, retinopathy and renal failure.[2]

One of the educational strategies to prevent complications of this chronic condition is using mobile applications that allow human-machine interaction through a set of interface characteristics by providing interactive experiences and facilitating data collection.[3,4] This communication technology has emerged as a new application model for self-care in which individuals take control of their health through information. Adolescents are a particular target group since they are among the users who most adopt applications in daily interactions.[5]

A study in China reports on important features of applications for better glycemic control in an educational intervention in type 1 diabetes *mellitus*.[6] First, the application must have features that provide greater support for day-to-day self-care behavior, including glycemic level monitoring, healthy food consumption habits, and regular insulin application. Furthermore, the application must include resources for recording physical activity practice, carbohydrate counting and interactive features that simulate problem solving related to emotional and psychosocial aspects.[7]

The conclusion of the study points to the need for attractive, easy-to-use applications that enable personalized features to motivate adolescents.[5] Although there are studies evaluating the use of applications for self-care in diabetes in the literature, there is a gap in the description of applications functionalities , which in the present study are examined as functionalities.[5-7]

The aim of this study was to examine the features of mobile applications for self-care of adolescents with type 1 diabetes *mellitus* reported on in the literature.

Methods

An integrative literature review was conducted, in which the results of studies already published on the subject of interest were gathered, evaluated and summarized. The following steps were taken to carry out this review: 1) formulation of the research question; 2) establishment of criteria for inclusion of studies and literature search; 3) presentation of the resources of revised primary studies; 4) interpretation of results; and 5) presentation of results and summary of content.[8]

The following question guided this integrative review: "What are the features in mobile applications for self care of adolescents with type 1 diabetes mellitus reported on in the literature"?

Queries were performed in the following databases: Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane Library, Latin American Literature in Health Sciences (LILACS), PubMed (National Library of Medicine), SCOPUS, and Web of Science. The following Health Science Descriptors (DeCS) and their respective descriptors in English and Spanish were used: "mobile applications", "self-care" and "type 1 diabetes *mellitus*".

Criteria for text selection included full text articles available electronically, published between 2012 and 2017, and focused on applications aimed at adolescents with type 1 diabetes *mellitus*. This time span covering the last five years to date is due to the fact that it represents a period where advances in the development of healthcare applications are expected.

Articles bearing no relation to the subject as identified in title and abstract; review articles; and those that did not meet the inclusion criteria were excluded.

A spreadsheet was prepared to categorize the articles that were classified with indication of date of retrieval, title of article, year of publication, age range of the study sample, duplication,

pertinence to the aim of the integrative review. Studies found in more than one database were considered only once.

The query results were reviewed independently by two of the authors based on the process of identification, eligibility and screening of articles. Any discrepancies in the coding were resolved in discussions with the other authors.

The search strategy yielded 248 articles. After reading the selected articles, 131 duplicate articles were excluded. Of the 117 articles left, 80 were excluded because they did not deal with adolescents as target users. Of the remaining 37 articles, 25 review articles or unrelated to the theme were excluded. A total of 12 articles addressed the guiding question and made up the final sample of the present review.

Figure 1 presents an overview of the process of integrative literature review.

The Agency for Healthcare Research and Quality (AHRQ) categorization was used for classification of the level of evidence of the studies.[9] The quality of the evidence is classified into six levels, namely: I - Evidence resulting from meta-analysis of multiple controlled and randomized clinical studies; II - Evidence obtained in individual studies with experimental design; III - Evidence from quasi-experimental studies; IV - Evidence from descriptive stud-

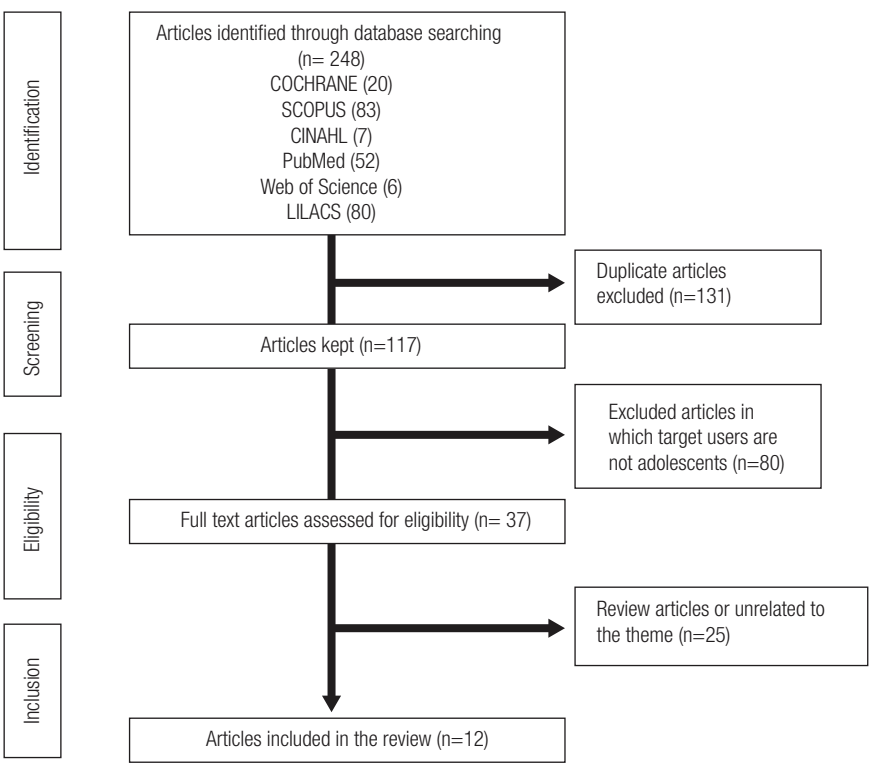

Figure 1. Diagram of identification, screening, eligibility and inclusion of studies in the integrative literature review

ies (non-experimental) or of qualitative approach; V - Evidence from case reports or experience; and VI - Evidence based on expert opinions.

After reading and analyzing the articles, a table describing the applications functionalities was elaborated.

As this is a review article, it is not subject to the Research Ethics Committee approval. Nevertheless, all ethical principles were adhered to, including copyright of cited sources.

Results

The 12 articles selected in this review were developed and published in the following countries: United States of America - USA (4), Austria (1), Norway (3), Canada (2), China (1) and United Kingdom (1). The distribution of articles according to year of publication was the following: 2016 (1), 2015 (5), 2014 (2) e 2012 (4). Two studies were classified as level of evidence IV, eight as level of evidence III; one as level II and one as level I, as shown in chart 1.

After reading and analyzing the articles, the applications functionalities were listed and organized by main function and goal, as described in chart 2.

Although no article described an application offering all functionalities, all articles described the implementation of at least one of them.

Chart 1. Description of studies included in the integrative review according to title, year of publication, country of authors, level of evidence, summary of conclusions and recommendations n = 12

Title	Author/Year/Country	Level of evidence	Summary of conclusions/recommendations
Improving diabetes care for young people with type 1 diabetes through visual learning on mobile phones: Mixed-methods study	Froisland, D., et al (2012)[10] Norway	Quasi-experimental study Level III	Participants reported greater understanding of diabetes self-care after using the Diamob application.
Design of an mHealth app for the self-management of adolescent type 1 diabetes: A pilot study	Cafazzo, J., et al (2012)[11] Canada	Quasi-experimental study Level III	Using in-app incentives was associated with improved frequency of glycemic monitoring.
Using mobile phones to measure adolescent diabetes adherence	Mulvaney SA., et al. (2012)[12] USA	Quasi-experimental study Level III	Mobile applications offer a viable method for glycemic monitoring and insulin administration in adolescents.
A pilot test of a tailored mobile and web-based diabetes messaging system for adolescents.	Mulvaney SA., et al. (2012)[13] USA	Quasi-experimental study Level III	The study results demonstrate the viability of the SuperEgo application in hyperglycemia treatment.
Preparing Adolescents With Chronic Disease for Transition to Adult Care: A Technology Program.	Huang JS., et al (2014)[14] USA	Individual study with experimental design Level II	Mentions several recommendations on the use of glycemic monitoring and health education resources in the MD2Me application.
Can smartphone-based logging support diabetologists in solving glycemic control problems?	Tiefengrabner M., et al (2014)[15] Austria	Quasi-experimental study Level III	The application offered the basis for recommendations that can improve participants' glycemic control.
Integrating visual dietary documentation in mobile-phone-based self-management application for adolescents with type 1 diabetes.	Frøisland DH., et al (2015)[16] Norway	Quasi-experimental study Level III	The study conclusion is that implementing the Diamob application helps adolescents to understand the basics of diabetes.
Performance of the first combined smartwatch and smartphone diabetes diary application study.	Årsand E., et al (2015)[17] Norway	Descriptive study Level III	The study demonstrated the My Diabetes application provides easy ways to monitor blood glucose, physical activity, and healthy eating information.
mHealth applications for diabetes: User preference and implications for app development.	Conway N., et al (2015) [18] United Kingdom	Descriptive study Level IV	The study demonstrated most participants would like to use an application to help with self-care management.
Technology Use for Diabetes Problem Solving in Adolescents with Type 1 Diabetes: Relationship to Glycemic Control.	Kumah-Crystal YA., et al (2015)[5] USA	Quasi-experimental study Level III	The study addresses important issues of using technology for problem solving in diabetes and self-management.
A Smartphone-Based Cloud Computing Tool for Managing Type 1 Diabetes in Ontarians.	Baskaran V., et al (2015)[19] Canada	Expert opinion Level VI	The study points the way to the successful implementation of a type 1 diabetes mellitus application involving minimal investment.
Welltang - A smart phone-based diabetes management application - Improves blood glucose control in Chinese people with diabetes	Zhou W., (2016)[6] China	Randomized controlled clinical study Level I	The application has messages encouraging users to initiate and/or maintain self-care behaviors, support their treatment plans, and improve their quality of life.

Chart 2. Application resources examined in the 12 articles of the integrative review

Function	Goal	Functionality
Glycemic control	Monitoring	Alarm sound
		Measurement record
		Award for goal achievement for glycemic control
		Data transfer via Bluetooth
Insulin therapy	Insulin application	Alarm sound
		Administration record
Diet	Carbohydrate counting	carbohydrate counting and record per portion
		Meal photo taking and sharing
Physical activity	Exercise practice	Practice record
		Step count
		Alarm sound
Approach to feelings	Perception of mood state	Use of emoticons
	Barrier identification	Coaching (self-care questions)
Social relationships	Family context	Graphs with weekly glycemic monitoring records
	Health professionals context	Message sending
	Peers context	Chat rooms

Discussion

Among all resources found in the applications of the 12 articles of this integrative review, the most present were alarm sound, record of glycemic measurement and insulin administration.[10,13] Lyons (2013) states that regular monitoring of glycemic levels at least three to four times a day with up to eight tests for specific adjustments is essential for adolescents to achieve glycemic control and reduce risks of complications.[20]

A study conducted in Canada with 20 adolescents aged 14-16 years had significant results in glycemic monitoring during the three-month use of an application in which the adolescent could transfer data from the glucometer to a mobile device via Bluetooth.[6] A similar study revealed that alarm sound with application feedback on clinical information led participants to reflect on the influence of behavior on glycemic control, and helped adolescents to take on decision making and problem-solving tasks.[5]

One of the advantages of alarm sound features in applications compared to an alarm clock and paper notes is the convenience of users being able to adjust the times of insulin administration as calculated per meal, and being reminded as to when the current and previous blood glucose levels were measured. This may be useful after a hypoglycemic event, allowing users to see and understand the effect of meal carbohydrates on glycemic indexes.[17,19]

In an educational intervention with adolescents in Norway an application featuring automatic transfer of glycemic values from a glucometer to a mobile device via Bluetooth was reported, which included photo taking of meals to discuss carbohydrate counts and insulin therapy. The study reported that adolescents improved their understanding of their chronic condition with increased self-efficacy for self-care.[10]

It is important to explore the use of mobile applications with self-care actions to understand adolescents' behavior regarding physical activity practice and weight control with options of inserting values of body mass index (BMI) and graphs visualization.[2] Some studies reported on applications offering options to choose the type of physical activity the adolescent wants to practice and its level of intensity and duration. These applications can provide easy ways to monitor step counts, physical activity goals in terms of days or minutes per week, and healthy eating tips before and after physical activity to prevent hypoglycemic episodes.[10,17]

These findings suggest that mobile applications with educational strategies for glycemic control may be more effective as they lead adolescents to reflect on their attitudes and take

responsibility for their health by encouraging them to overcome everyday barriers and set self-care goals.[18]

Therefore, functionalities related to health education in the applications play an important role in self-care management in chronic conditions, since adolescents' knowledge and skills are improved.[14] Health education can influence positively, as insulin injection in inappropriate parts of the body, lack of nutritional knowledge and carbohydrate counting techniques are factors frequently related to lack of confidence and consequently, to treatment failure.[5]These factors suggest that applications should have resources to guide adolescents on how to properly administer insulin and monitor glycemic levels, reporting signs and symptoms of hypoglycemia or hyperglycemia, and forms of acting in each situation hence minimizing insecurities and collaborating in diabetes management.[12]

A study proposes making up for the shortage of health professionals' time to educate users through the use of self-care mobile applications, which can provide decision support for self-care and optimize treatment for each individual.[5] In view of this, applications can help adolescents to understand their treatment goals and set goals for self-care that can be individually adjusted, taking into account the degree of empowerment for self-care practices and time of diagnosis.[5,10]

Some authors state that applications developed for self-care in diabetes should consider adolescents' preferences in order to be efficient, useful and enjoyable.[3,18] In addition, applications should have functionalities that are gender and opinion sensitive so as to improve usability and cater for more participants.[4] Therefore, applications aimed at supporting behavior changes should be user-centered to foster motivation and interest in using them.[21-22]

Engaging adolescents in diabetes care is one of the main challenges of an educational intervention for health behavior change. One of the strategies used to encourage adolescents to use the application included the goal achievement award for glycemic control including interactive elements, such as goal achievement score, competition, and decision making. Among the selected studies, there is an association between rewards and improved frequency of glycemic monitoring, since this resource increases the intrinsic motivation for self-care and adolescents' competence to reach their goals.[2,12,15]

Based on adolescents' resistance to approach healthcare professionals, a study sought to promote interaction through messages sent by an application.[7] Another study added an in-app feature for users' communication with their peers in a chat room to share experiences and obtain or provide support.[13]

Although there is readily available information about type 1 diabetes *mellitus*, glycemic control in adolescence relies on family support for decision making for improved glycemic control.[4,16] Adolescents are willing to share results of glycemic monitoring with their parents by sharing weekly records graphs, although a study mentioned the supervision of monitoring with use of an application as a source of conflict and anxiety between parents and children.[10,19]

Applications are strongly recommended to include features related to sentiment record and analysis, such as emoticons for mood identification. Maintaining good glycemic control often generates feelings such as sadness, denial, anguish, and in some cases, revolt, making self-care practice difficult.[11,22-24] Another feature used for sentiment record is coaching with the objective to identify barriers and motivate users for decision making and achievement of self-care goals.[6]

Although 12 articles were included in the results of this review, the number of researchers working on the subject is actually smaller, as some of the reviewed articles were authored by the same research group.[10-13,16] Therefore, the lack of studies and dissemination of this subject among the Brazilian population demonstrate the importance of this integrative review.

Among the limitations of this study are descriptors used since they are not consistent in all databases, which may have contributed to the fact of

not retrieving further available studies. No available access to the applications reported on in the articles is another limitation, which prevented testing the applications themselves. For an overview of the applications we had to rely on their reported features.

Conclusion

The functionalities of the applications reported on in the reviewed articles in terms of functions (glycemic control, insulin therapy, diet, physical activity, sentiment record and analysis and social relations) were pointed as significant to aid in glycemic control. The results presented in this study are expected to be useful to inform the development of new applications incorporating functionalities for improved self-care of adolescents with type 1 diabetes *mellitus*.

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Collaborations

Chaves FF participated in the project design, data analysis and interpretation, and article drafting. Carvalho TLA collaborated with data analysis and interpretation, and writing of the article. Paraíso EC, Pagano AS, Reis IA and Torres HC contributed to the project design, article writing, critical review of the relevant intellectual content and final approval of the version to be published.

References

1. International Diabetes Federation. Diabetes atlas [Internet]. 7th ed. Belgium: International Diabetes Federation; 2015 [cited Jan 23 2017]. Available from: file:///C:/Users/UFMG/Downloads/IDF_Atlas%202015_UK.pdf.
2. Ho Y, O'Connor BH, Mulvaney SA. Features of online health communities for adolescents with type 1 diabetes. West J Nurs Res. 2014; 36(9):1183-98.
3. Cavalcante RB, Ferreira MN, Maia LL, Araújo A, Silveira AA. Use of information technologies and communication in health education for adolescent students. J Health Inform. 2012; 4(4):182-6.
4. Pulman AJ, Taylor J, Galvin K, Masding MG. Designing mobile applications to support type 1 diabetes education. World conference on mobile and contextual learning [Internet]. 2012. [cited 2017 Oct 29]. Available from:http://ceur-ws.org/Vol-955/papers/paper_11.pdf.
5. Kumah-Crystal YA, Hood KK, Ho YX, Lybarger CK, O'Connor BH, Rothman RL, et al. Technology use for diabetes problem solving in adolescents with type 1 diabetes: relationship to glycemic control. Diabetes Technol Ther. 2015; 17(7): 449-54.
6. Zhou W, Chen M, Yuan J, Sun Y. Welltang - A smart phone-based diabetes management application - Improves blood glucose control in Chinese people with diabetes. Diabetes Res Clin Pract. 2016; 116:105-10.
7. Drion I, Pameijer LR, Van Dijk PR, Groenier KH, Kleefstra N, Bilo HJ. The effects of a mobile phone application on quality of life in patients with type 1 diabetes mellitus a randomized controlled trial. J Diabetes Sci Technol. 2015; 9(5):1086-91.
8. Ganong LH. Integrative reviews of nursing research. Res Nurs Health. 1987; 10(1):1-11.
9. Oxford Centre for Evidence-based Medicine: levels of evidence [Internet]. 2009 [cited 2017 Jan 20]. Available from: http://www.cebm.net/oxford-centre-evidence-based-medicine-levels-evidence-march-2009.
10. Froisland D, Arsand E, Skarderud, F. Improving diabetes care for young people with type 1 diabetes through visual learning on mobile phones: Mixed-methods study. J Med Internet Res. 2012; 14(4):e111.
11. Mulvaney SA, Anders S, Smith AK, Pittel EJ, Johnson KB. A pilot test of a tailored mobile and web-based diabetes messaging system for adolescents. J Telemed Telecare. 2012; 18(2):115-8.
12. Lyons EJ, Hatkevich C. Prevalence of behavior changing strategies in fitness video games: theory-based content analysis. J Med Internet Res. 2013; 15(5):e81.
13. Årsand E, Muzny M, Bradway M, Muzik J, Hartvigsen G. Performance of the First Combined Smartwatch and Smartphone Diabetes Diary Application Study. J Diabetes Sci Technol. 2015; 9(3): 556-63.
14. Baskaran V, Prescod F, Dong L. A Smartphone-based cloud computing tool for managing type 1 diabetes in Ontarians. Can J Diabetes. 2015; 39 (3):200-3.
15. Conway N, Campbell I, Forbes P, Cunningham S, Wake D. mHealth applications for diabetes: User preference and implications for app development. Health Informatics J. 2016; 22(4):1111-20.
16. Huang JS, Terrones L, Tompane T, Dillon L, Pian M, Gottschalk M, et al. Preparing Adolescents With Chronic Disease for Transition to Adult Care: A Technology Program. Pediatrics. 2014; 133(6): e1639-e1646.
17. Mulvaney SA, Rothman RL, Dietrich MS, Wallston KA, Grove E, Elasy TA, et al. Using mobile phones to measure adolescent diabetes adherence. Health Psychol. 2012; 31(1):43-50.
18. Grossi LM, Pisa IT, Marin HF. Oncoaudit: desenvolvimento e avaliação de aplicativo para enfermeiros auditores. Acta Paul Enferm. 2014; 27(2):179-85.
19. Pagoto S, Schneider K, Jojic M, DeBiasse M, Mann D. Evidence-Based Strategies in Weight-Loss Mobile Apps. Am J Prevent Med. 2013; 45 (5):576-82.
20. Tiefengrabner M, Domhardt M, Oostingh GJ, Schwenoha K, Stütz T, Weitgasser R, et al. Can smartphone-based logging support diabetologists in solving glycemic control problems? Clifton: IOS Press Book; 2014 v.198. p. 188-95. [Studies in Health Technology and Informatics].

21. Frøisland DH, Årsand E.Integrating visual dietary documentation in mobile-phone-based self-management application for adolescents with type 1 diabetes. J Diabetes Sci Technol. 2015; 9(3):541-8.

22. Cafazzo J, Casselman M, Hamming N, Katzman D, Palmert M. Design of an mhealth app for the self-management of adolescent type 1 diabetes: a pilot study. J Med Internet Res. 2012; 8;14(3):e70.

23. Vikraman B, Franklyn P, Linying D. A smartphone-based cloud computing tool for managing type 1 diabetes in Ontarians. Can J Diabetes. 2015; 39(3):200-3.

24. Anderson K, Burford O, Emmerton L. App Chronic Disease Checklist: Protocol to Evaluate Mobile Apps for Chronic Disease Self-Management. JMIR Res Protoc. 2016; 4;5(4):e204.