Using Digital Health Technology to Prevent and Treat Diabetes

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Introduction

THIS ARTICLE PRESENTS SOME OF the important articles from July 2016 through June 2017 regarding digital interventions to prevent and treat diabetes. The number and quality of publications which could have been selected for this review have increased from year to year, demonstrating how the field is continuously growing stronger.

As the world of digital health interventions has become more robust and more complex, a new challenge, and therefore a new opportunity, has emerged—how to bring proven-effective digital interventions to scale. While this new opportunity has not been the subject of many papers or studies, it is becoming increasingly important. There have been countless digital interventions that have been proven effective but have failed to live up to their potential to result in real and sustained population-level effects.

There are several reasons for this failure, including: (1) the inability to engage and successfully recruit participants to show up for the intervention; (2) the lack of sufficient engagement in the intervention to have a big enough dose effect; and (3) the lack of a sustainable infrastructure on which to place the effective intervention. The first two are what most would identify as the biggest challenges. Research and real-world experience are critically needed to crack the engagement challenge.

The true major challenge is the lack of infrastructure. It is a classic example of a market failure. Consumers want the service, providers are available to offer the service, and payers are willing to pay for the direct cost to provide the service to their members and patients, but there are insufficient resources to provide the infrastructure so vital for successful deployment at scale. This is despite the millions of dollars invested by local, state, and national governments and foundations and the extraordinary efforts by program providers and other stakeholders.

One promising approach to address this market failure is to offer consumers the same intervention both in person and digitally. It is hoped that the increased volume of participants generated by providing two program formats will be enough to support the needed infrastructure. More likely, much like the ways governments support highways and other necessary infrastructure, there will be a need for financial governmental support. In addition to the provision of the service, examples of the elements needed to successfully form such an infrastructure include:

1. Service delivery: e.g., space (in-person), coach training and management, participant recruitment, provider network management (in-person), quality assurance, and outcome evaluation
2. Administrative support: e.g., contracting, client success, billing, legal/regulatory, reporting, information technology (IT) platform, and financing
3. Sales and marketing support: e.g., purchaser marketing and sales, client acquisition

So I ask that you stay tuned. I hope there will be publications in the coming years that begin to demonstrate solutions for bringing effective digital interventions to scale.

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Key Articles Reviewed for the Article

Challenges in diabetes care: can digital health help address them?

Iyengar V, Wolf A, Brown A, Close K

[Clin Diabetes 2016; 34: 133–141](#)

Developing and evaluating digital interventions to promote behavior change in health and health care: recommendations resulting from an international workshop

Michie S, Yardley L, West R, Patrick K, Greaves F

[J Med Internet Res 2017; 19: e232](#)

Do web-based interventions improve well-being in type 2 diabetes? A systematic review and meta-analysis

Hadjiconstantinou M, Byrne J, Bodicoat DH, Robertson N, Eborall H, Khunti K, Davies MJ

[J Med Internet Res 2016; 18: e270](#)

A systematic review of reviews evaluating technology-enabled diabetes self-management education and support

Greenwood DA, Gee PM, Fatkin KJ, Peebles M

[J Diabetes Sci Technol 2017; 11: 1015–1027](#)

A diabetes self-management program: 12-month outcome sustainability from a nonreinforced pragmatic trial

Lorig K, Ritter PL, Turner RM, English K, Laurent DD, Greenberg J

[J Med Internet Res 2016; 18: e322](#)

Impact of information technology-based interventions for type 2 diabetes mellitus on glycemic control: a systematic review and meta-analysis

Alharbi NS, Alsubki N, Jones S, Khunti K, Munro N, de Lusignan S

[J Med Internet Res 2016 25; 18: e310](#)

Effect of telemedicine on glycated hemoglobin in diabetes: a systematic review and meta-analysis of randomized trials

Faruque LI, Wiebe N, Ehteshami-Afshar A, Liu Y, Dianati-Maleki N, Hemmelgarn BR, Manns BJ, Tonelli M, for the Alberta Kidney Disease Network

[CMAJ 2017; 189: E341–E364](#)

Telemedicine for the management of glycemic control and clinical outcomes of type 1 diabetes mellitus: a systematic review and meta-analysis of randomized controlled studies

Lee SWH, Ooi L, Lai YK

[Front Pharmacol 2017; 8: 330](#)

Effectiveness of mHealth interventions for patients with diabetes: an overview of systematic reviews

Kitsiou S, Paré G, Jaana M, Gerber B

[PLoS One 2017; 12: e0173160](#)

Understanding factors affecting patient and public engagement and recruitment to digital health interventions: a systematic review of qualitative studies

O'Connor S, Hanlon P, O'Donnell CA, Garcia S, Glanville J, Mair FS

[BMC Med Inform Decis Mak 2016; 16: 120](#)

The effectiveness of prompts to promote engagement with digital interventions: a systematic review

Alkhalidi G, Hamilton FL, Lau R, Webster R, Michie S, Murray E

J Med Internet Res 2016; **18**: e6

Do health information technology self-management interventions improve glycemic control in medically underserved adults with diabetes? A systematic review and meta-analysis

Heitkemper EM, Mamykina L, Travers J, Smaldone A

J Am Med Inform Assoc 2017; **24**: 1024–1035

The effectiveness of e- & mHealth interventions to promote physical activity and healthy diets in developing countries: a systematic review

Müller AM, Alley S, Schoeppe S, Vandelanotte C

Int J Behav Nutr Phys Act 2016; **13**: 109

The effect of text message support on diabetes self-management in developing countries—a randomised trial

Van Olmen J, Kegels G, Korachais C, de Man J, Van Acker K, Kalobu JC, van Pelt M, Ku GM, Hen H, Kanda D, Malombo B, Darras C, Schellevis F

J Clin Transl Endocrinol 2017; **7**: 33–41

The effect of technology-mediated diabetes prevention interventions on weight: a meta-analysis

Bian RR, Piatt GA, Sen A, Plegue MA, De Michele ML, Hafez D, Czuhajewski CM, Buis LR, Kaufman N, Richardson CR

J Med Internet Res 2017; **19**: e76

Web-based interventions for weight loss or weight loss maintenance in overweight and obese people: a systematic review of systematic reviews

Sorgente A, Pietrabissa G, Manzoni GM, Re F, Simpson S, Perona S, Rossi A, Cattivelli R, Innamorati M, Jackson JB, Castelnuovo G

J Med Internet Res 2017; **19**: e229

Outcomes of a digital health program with human coaching for diabetes risk reduction in a Medicare population

Castro Sweet CM, Chiguluri V, Gumpina R, Abbott P, Madero E, Payne M, Happe L, Matanich R, Renda A, Prewitt T

J Aging Health 2017; Jan 1: 898264316688791. [Epub ahead of print] DOI 10.1177/0898264316688791

Diabetes self-management training in a virtual environment

Reagan L, Pereira L, Jefferson V, Kreider KE, Totten S, D'Eramo Melkus G, Johnson C, Vorderstrasse A

Diabetes Educ 2017; **43**: 413–421

Guidelines for the gamification of self-management of chronic illnesses: multimethod study

AlMarshedi A, Wills G, Ranchhod A

JMIR Serious Games 2017; **5**: e12

Challenges in diabetes care: can digital health help address them?

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Clin Diabetes 2016; **34**: 133–141

Background

Digital health solutions have great potential to solve important problems, but they have significant challenges before

they can have real impact. The field is still in its nascent days and time will tell how impactful these approaches will become.

Methods

This review, based on personal experience and learnings, provides information on the current state of the digital health field and offers suggestions for how to maximize benefits from these approaches.

Results

Current challenges include: (1) worsening patient to provider ratios; (2) geographic barriers to accessing care; (3) patient burden; (4) provider burden; (5) economic burden; and (6) no improvement in A1c outcomes. Approaches digital health could use: (1) cloud-connected glucose systems; (2) telehealth services; (3) data management platforms; (4) type 2 diabetes prevention programs; (5) clinically validated mobile apps; and (6) social media.

Conclusions

Excellence in diabetes care requires new thinking, and existing trends seem to be driving us in the direction of more digital solutions. Digital health is not and will never be the only answer, but it could become an integral part of the diabetes toolbox.

Comments

This article is a well-written and thoughtful description of key approaches to digital health, giving a clear and understandable review of current challenges and a taxonomy to understand various digital health approaches. The authors highlight the challenges and opportunities with each of the digital approaches. It is well worth reading for an excellent summary of each approach and an overview of the current state of the art technology as well as a look into the future trajectory of the field.

Developing and evaluating digital interventions to promote behavior change in health and health care: recommendations resulting from an international workshop

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J Med Internet Res 2017; **19**: e232

Background

Programs and devices using digital technology show great promise as a way to foster and support behavior change. Developing and evaluating digital interventions require use of improved and perhaps entirely new methods for research and evaluation. This article summarizes some of these challenges and suggests approaches designed to advance the field. Areas addressed include intervention development in a rapidly changing technological landscape, promoting user engagement, advancing the underpinning science and theory, evaluating effectiveness and cost-effectiveness, and addressing issues of regulatory, ethical, and information governance.

Methods

This article is the result of a two-day international workshop on how to create, evaluate, and implement effective digital interventions in relation to health behaviors. It was held in London in September 2015.

Results

Interventions should comply with existing regulatory frameworks, but with consideration for emerging standards around information governance, ethics, and interoperability. The potential of digital interventions for testing and advancing theories of behavior change by generating ecologically valid, real-time objective data was recognized. It was noted that sustained engagement is not always required and that for each intervention it is useful to establish what constitutes sufficient engagement to achieve the intended outcomes.

Conclusions

Evaluations should include all phases of the development cycle, designed for generalizability, and consider new experimental designs to make the best use of rich data streams. Future health economics analyses need to recognize and model the complex and potentially far reaching.

Comments

This paper will be particularly interesting to individuals who are involved in the process of building and evaluating the impact of digital interventions. It is a well thought out description of challenges in the process of creating an intervention, what should be done to maximize the impact of any intervention, and how to evaluate this impact.

Do web-based interventions improve well-being in type 2 diabetes? A systematic review and meta-analysis

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J Med Internet Res 2016; **18**: e270

Background

Inadequate diabetes self-care can lead to a negative impact on quality of life and psychological well-being. Even though there is limited evidence to show the effectiveness of web-based psychological support in people with type 2 diabetes, a web-based approach is becoming popular due to the lack of traditional psychological support and the barriers to face-to-face education programs. The objective of this systematic review is to critically assess the effectiveness of web-based interventions that aim to improve well-being in people with type 2 diabetes.

Methods

Searches were conducted using the electronic databases MEDLINE (Medical Literature Analysis and Retrieval System Online), Embase, CINAHL (Cumulative Index to Nursing and Allied Health Literature), PsycINFO, and Cochrane Library, and a meta-analysis was carried out for depression and distress outcomes.

Results

Of the 16 randomized, controlled studies that met the criteria for systematic review, nine were included in the meta-analysis. Theories were applied to many of the interventions. The most common behavior change techniques were “tracking/monitoring” and “general information.” Interventions held within a period of 2 to 6 months providing professional-led support with asynchronous and synchronous communication appeared to be associated with significant well-being outcomes. The mean [95% confidence interval] difference between the intervention and control arms at follow-up on depression score was -0.31 [-0.73 , 0.11]. The mean difference on distress scores at follow-up was -0.11 [-0.38 , 0.16]. No significant change in depression ($P=0.15$) or distress ($P=0.43$) were found following meta-analyses.

Conclusions

While the results of the meta-analyses were not significant for distress and depression scores, this review demonstrated that web-based interventions have the potential to improve well-being outcomes for type 2 diabetics.

Comments

This review determined whether patients' well-being was improved by web-based interventions. This outcome is key to improving self-management, and it was encouraging to see that some of the studies showed positive results. It was not surprising that outcomes varied considerably among the various interventions. It is critical that future studies include patient defined well-being as part of the outcomes. One promising measurement

approach is called Ecological Momentary Assessment. Participants are periodically and randomly asked to indicate their state of well-being or other in-the-moment variables (such as pain, self-efficacy, and anxiety) to build a rich and varied profile of each individual, which can help with patient management and outcome analysis.

A systematic review of reviews evaluating technology-enabled diabetes self-management education and support

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J Diabetes Sci Technol 2017; **11**: 1015–1027

Background

Since the widespread use of mobile devices, technology has been used more and more to enable diabetes self-management, support, and education. This systematic review provides an overview of how currently available technology affects various outcomes for people who live with diabetes.

Methods

High-quality review articles and meta-analyses published between January 2013 and January 2017 that focused on utilizing technology in diabetes self-management and education were used to comprise a systematic review.

Results

Of the twenty-five studies included in this analysis, the majority evaluated the use of mobile phones and secure messaging. Most studies evaluated healthy eating, being active, and metabolic monitoring as predominant self-care behaviors. Eighteen reviews listed the reduction of A1c as a significant outcome measure. Four key elements appear to be required for improved A1c levels: communication, patient-generated health data, education, and feedback.

Conclusion

Technology-enabled diabetes self-management solutions were shown to significantly improve A1c. The most effective interventions incorporated all the components of a technology-enabled feedback loop. This feedback loop connected people with diabetes and their health-care team using 2-way communication, analyzed patient-generated health data, tailored education, and individualized feedback. This systematic review shows evidence indicating that organizations, policy makers, and payers should consider incorporating these solutions into the design of diabetes self-management education and support services for population health and value-based care models. Due to the ever-growing presence of mobile phones, the reach and access to diabetes self-management education and ongoing support can be improved

by using digital health solutions that incorporate evidence-based, behaviorally designed interventions.

Comments

The authors chose to summarize other articles (published from 2013 to 2017) from around the world which have reviewed the impact of technology-enabled self-management education and support on outcomes for patients with diabetes. The reviews primarily focused on mobile phones, secure messaging, and web-based information. While improvement in A1c was seen in most reviews, there was minimal analysis of other important outcomes such as problem solving, reducing risk, and healthy coping behaviors. One noteworthy outcome was that feedback between the patient and the health-care team resulted in better outcomes. As seen in other studies and reviews, the promise of digital approaches is great, while the outcomes are still modest at best. The hope for the future is that more interventions combine evidence-based approaches with behaviorally designed interventions to improve the reach of and access to diabetes self-management education and ongoing support.

A diabetes self-management program: 12-month outcome sustainability from a nonreinforced pragmatic trial

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J Med Internet Res 2016; **18**: e322

Background

Controlled trials have shown that diabetes self-management education is effective. In a 6-month translation study, the 6-week Better Choices, Better Health–Diabetes (BCBH-D) self-management program was also associated with an improvement in health outcomes. The objective of this study was to determine whether, after a 1-year intervention, there were improvements in health outcomes (including glycated hemoglobin [HbA1c]) and health behaviors (including recommended medical tests) due to the BCBH-D self-management program, which was offered both web-based and face-to-face.

Methods

Face-to-face workshops took place in Atlanta, Indianapolis, and St. Louis, while web-based programs were administered nationally. Self-report questionnaires were administered by mail or were web-based and collected health and health-behavior measures. HbA1c blood samples were collected via mailed kits. In an earlier 6-month study, 13 of 14 outcome measures, including HbA1c, showed statistically significant improvement. This study compared baseline with 1-year outcomes using paired *t* test. Subgroup analyses were used to examine whether participants who had specific conditions such as hypoglycemia, depression, high HbA1c, non-

adherence to medication, or no aerobic exercise improved. The percentage of participants who exhibited improvements in effect size >0.4 in at least one of the five measures was also calculated.

Results

Overall, 857 participants with 1-year data (69.7% of baseline participants) showed statistically significant improvements in 13 of 15 outcome measures at the 1-year mark. Additionally, 685 of these participants (79.9%) had improvements in effect size of ≥ 0.4 in at least one of the five criterion measures.

Conclusion

Small but significant benefits were seen in multiple measures for the study participant, and improvements that were previously noted at 6 months were maintained or increased at 1 year.

Comments

Since one of the authors of this article (N.K.) has a conflict of interest (his company markets the intervention studied), no comments will be offered for this article.

Impact of information technology-based interventions for type 2 diabetes mellitus on glycemic control: a systematic review and meta-analysis

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J Med Internet Res 2016 **25**; **18**: e310

Background

Information technology-based interventions are being used more and more in managing health-care, but there is still conflicting evidence as to whether they improve outcomes in people with type 2 diabetes. The purpose of this study was to conduct a meta-analysis and systematic review of clinical trials, assessing the changes in HbA1c levels caused by information technology, and to use chronic care model (CCM) elements to map the interventions.

Methods

Independent reviewers searched the electronic databases Embase and PubMed to identify relevant studies published up until July 2016. This method was then reinforced by using the electronic search tools to find articles from the references of the articles already selected. Out of 1082 articles found, 32 trials (in 40,454 patients) were included. The pooled results were estimated using a random-effects model.

Results

There was a statistically significant reduction in HbA1c levels (mean difference -0.33% [95% CI $-0.40, -0.26$], $P < 0.001$) associated with information technology-based

interventions. The largest to smallest reduction of HbA1c levels are seen in studies focusing on electronic self-management (0.50%), electronic medical records (0.17%), an electronic decision support system (0.15%), and a diabetes registry (0.05%), respectively. Furthermore, improvements in HbA1c levels were directly related with the degree of CCM-incorporation in the information technology-based interventions.

Conclusion

For people with diabetes, glycemic control was improved by combining information technology strategies and other elements of chronic care models. While there was evidence showing the cost of care was lower, there was no observable clinically relevant impact on low-density lipoprotein levels and blood pressure.

Comments

This analysis, while similar in goals to the other efficacy reviews in this article, adds additional information by the types of programs reviewed. The lack of impact from diabetes registries is not surprising; though they can be quite useful in increasing the effectiveness and efficiency of outreaching to target populations, they will only be as effective as the program to which the participant gains access. It is encouraging to see that decision support and self-management support systems have an impact. Electronic medical records can be expected to have an impact if they help improve providers' performance and/or give patients access to important data and information.

Effect of telemedicine on glycated hemoglobin in diabetes: a systematic review and meta-analysis of randomized trials

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CMAJ 2017; **189**: E341–E364

Background

The use of telecommunications to deliver health services, known as telemedicine, is an unproven but potentially promising intervention for improving diabetes care quality. We summarized the efficacy of various methods of telemedicine for the management of diabetes compared with standard care.

Methods

MEDLINE, Embase, the Cochrane Central Register of Controlled Trials databases (to November 2015), and ref-

erence lists of existing systematic reviews were searched for randomized controlled trials (RCTs) comparing telemedicine with standard care for adults with diabetes. Two independent reviewers assessed risk of bias in the studies and selected studies. The primary outcome was HbA1C reported at three time points (≤ 3 , 4–12, and > 12 months). Other outcomes measured were quality of life, mortality, and episodes of hypoglycemia. Heterogeneity was quantified using the I^2 statistic, and trials were pooled using random-effects meta-analysis.

Results

We identified 111 eligible RCTs ($n=23,648$) from 3688 citations. Telemedicine achieved modest yet significant reductions in HbA1C in all three follow-up periods. Difference in mean at ≤ 3 months was -0.57% [95% confidence interval (CI) -0.74% , -0.40% (39 trials)]; at 4–12 months, the difference in mean was -0.28% [95% CI -0.37% , -0.20% (87 trials)]; and at > 12 months the difference was -0.26% [95% CI -0.46% , -0.06% (5 trials)]. Quantified heterogeneity (I^2 statistic) was 75%, 69%, and 58%, respectively. In meta-regression analyses, the effect of telemedicine on HbA1C appeared greatest in trials where medication adjustment was facilitated by telemedicine, those in which providers communicated with patients using text messaging or web portals, and in those with higher HbA1C concentrations at baseline. However, there was no convincing effect on mortality, quality of life, or hypoglycemia.

Conclusion

Compared with typical care, the addition of telemedicine, particularly systems that allow medication adjustments with or without a web portal or text messaging, led to improved HbA1c levels. However other clinically relevant outcomes were not improved.

Comments

Comments for this group of three articles (of which this is the first) are presented after Kitsiou et al.

Telemedicine for the management of glycemic control and clinical outcomes of type 1 diabetes mellitus: a systematic review and meta-analysis of randomized controlled studies

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Front Pharmacol 2017; **8**: 330

Background

For patients with chronic diseases in remote and underserved regions, telemedicine has been shown to be a successful way of providing care, allowing improved access to care while reducing health-care costs. However, there is scarce and conflicting evidence surrounding its applicability to type 1 diabetes. The objective of this study is to synthesize evidence and

quantify the effectiveness of telemedicine interventions for the management of glycemic and clinical outcomes in type 1 diabetes patients relative to comparator conditions.

Methods

Sources such as MEDLINE, Embase, Cochrane Library, Web of Science, PsycINFO, and CINAHL were searched for published articles from inception until December 2016. The study selection included the original articles reporting the results of randomized controlled studies on the effectiveness of telemedicine in people with type 1 diabetes. Two reviewers independently extracted the data and synthesized it by assessing the quality and strength of the evidence. Interventions were then categorized based on the telemedicine focus (education, monitoring, case management, consultation, and peer mentoring). The absolute change from baseline to follow-up assessment in glycosylated hemoglobin A1c (HbA1c) was then measured.

Results

In the 41 articles accumulated, 38 studies were identified. In studies examining telemedicine, positive effects on glycemic control were found with a mean reduction of 0.18% at the end of intervention. Longer studies (>6 months) that recruited patients who had higher baseline HbA1c (9%) were linked with larger effects. The telemedicine interventions that were more effective in improving glycemic control involved individualized assessments, audit with feedback, and skill building. There were no observed benefits, however, on blood pressure, lipids, weight, quality of life, and adverse events.

Conclusion

Based on our review, the evidence to support telemedicine to address glycemic control and other clinically relevant outcomes in type 1 diabetes is insufficient.

Effectiveness of mHealth interventions for patients with diabetes: an overview of systematic reviews

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Background

Diabetes is a widespread chronic illness that places an extraordinary strain on health-care systems across the globe. Mobile health technologies, known as mHealth, including wearable devices, smartphones, and mobile applications, offer significant and innovative opportunities for bettering diabetes self-management and bettering communication between patients and providers. The aim of this overview is to critically assess and consolidate findings from multiple sys-

tematic reviews regarding the effectiveness of mHealth interventions for patients with diabetes and to inform policy makers, practitioners, and researchers of these results.

Methods

An exhaustive search on multiple databases was performed to find relevant systematic reviews that were published between January 1996 and December 2015. Two authors then individually chose reviews, pooled the data, and used AMSTAR to assess the methodological quality of included reviews.

Results

Eligible for inclusion were fifteen systematic reviews published between 2008 and 2014. Most reviews had important methodological limitations and were of varying quality. The reviews that provided the most direct evidence show that on average, mHealth interventions improve glycemic control (HbA1c) compared with standard care or other non-mHealth approaches by as much as 0.8% for patients with type 2 diabetes and 0.3% for patients with type 1 diabetes, at least in the short term (12 months). Due to the limited quality of the evidence as a whole, further research will have a critical impact on the estimations of effect presented here.

Conclusions

Findings are consistent with clinically relevant improvements, especially regarding patients with type 2 diabetes. Like home telemonitoring, the implementation of mHealth interventions offer a promising approach for diabetes self-management.

Comments

These three studies attempted to review the impact of (1) “telemedicine” and (2) “mHealth” on diabetes outcomes and revealed modest improvements in glycemic control. Reviews of reviews make it very difficult to draw any valid conclusions, and these articles are no exceptions. They are worth including in the yearbook for their summaries of the different approaches: telemedicine as a way for patients and providers to interact remotely, and mHealth as the use of mobile and internet technologies to support individuals in managing their diabetes. Given the rapid pace at which these approaches evolve, one needs to be critical in accepting the conclusions from any study or review. Attention should not be exclusively focused on the technology, but rather on the evidence base for the chosen approach and the materials used. The best technology-enabled interventions are based on in-person protocols with proven impact on the specific target population(s).

Understanding factors affecting patient and public engagement and recruitment to digital health interventions: a systematic review of qualitative studies

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BMC Med Inform Decis Mak 2016; **16**: 120

Background

There are many types of digital health interventions (DHIs) available to patients and the public. However, there are many factors that affect their ability to engage and enroll in them. This systematic review intends to identify and synthesize the qualitative literature on facilitators and barriers to recruitment and engagement to DHIs to inform future application efforts.

Methods

English language qualitative studies from 2000 to 2015 that discussed factors affecting enrollment and engagement in a range of DHIs (e.g., “telemedicine,” “mobile applications,” “personal health record,” and “social networking”) were searched using PubMed, MEDLINE, CINAHL, Embase, Scopus, and the ACM (Association for Computing Machinery) Digital Library. A total of 1448 records were identified using text mining and additional search strategies. Two reviewers individually executed paper screening, quality assessment, data extraction, and analysis. Informed by normalization process theory, data was analyzed using framework synthesis, and burden of treatment theory helped conceptualize the interpretation of results.

Results

The review included nineteen publications, and during the process, four overarching themes that affect public and patient enrollment and engagement in DHIs emerged: (1) motivation and personal agency, (2) personal life and values, (3) the engagement and recruitment approach, and (4) the quality of the DHI. To spotlight the key methods of this review, an initial digital health engagement model (DIEGO) was developed. Several recommendations were made for future research due to the identification of existing knowledge gaps. Limitations of the study include the use of only publications that are published in English and the exclusion of gray literature.

Conclusion

The intricacy of digital health recruitment and engagement are emphasized and summarized. The review also outlines problems that should be resolved prior to patient and public commitment to and the effective implementation of digital health. More work is needed on three fronts: more effective engagement strategies, higher quality personalized digital solutions, and when appropriate, clinical endorsement and accreditation. Also, further investment is needed to progress computer literacy and ensure that technologies are affordable and available for those who wish to use them.

Comments

We are so pleased to include this article about how to increase participant engagement in digital interventions. We and our colleagues have all learned the hard way that having an engaging and effective digital intervention is necessary, but not sufficient, to have real impact at a population level. Interventions actually begin with outreach and continue with activation, sign-up, show-up, participation, and success. If all elements of this process are not successful, participants will not be able to benefit from the program, and purchasers will not get the results they need to offer the programs to even more people. The recent past has shown that collectively we can create great interventions. Time will tell if we will be able to engage enough people in these programs for the programs to have the clinical and financial outcomes necessary for them to survive.

The effectiveness of prompts to promote engagement with digital interventions: a systematic review

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J Med Internet Res 2016; **18**: e6

Background

Many health outcomes and behaviors have been improved using digital interventions. They are increasingly being used in various health-care areas such as health promotion, mental health, and self-management of long-term conditions. However, digital interventions have not been able to reach their full potential due to a lack of user engagement. There is an immediate need to develop effective strategies, such as technology-based reminders and prompts, that can promote users' engagement with digital interventions. The purpose of this review is to assess the effectiveness of promoting engagement in digital interventions with technology-based strategies.

Methods

Cochrane Collaboration guidelines on systematic review methodology were executed across seven electronic databases. These databases include the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, Embase, Web of Science, the Education Resources Information Center (ERIC), PsycINFO, and CINAHL. Database searches included results from their time of creation to September 13, 2013, and did not include restrictions on language or publication type. The search was conducted using three concepts: randomized controlled trials, digital interventions, and engagement. Reference lists of included studies and gray literature were searched as well. Two authors independently screened titles and abstracts and selected potentially eligible

papers, the full texts of which were obtained and double-screened. One author extracted data from the selected papers and another checked for accuracy. The Cochrane risk of bias assessment tool was used to assess any bias. Narrative synthesis was performed on all included studies and, where appropriate, data were pooled using meta-analysis. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to report all findings.

Results

In all, 8774 participants across 14 studies were included in the review, and 9 of the studies contained sufficient data to be a part of the meta-analysis. Compared with no strategy, the meta-analyses suggested that technology-based strategies can potentially promote engagement for dichotomous outcomes (relative risk [RR] 1.27, [95% CI 1.01, 1.60], $I^2 = 71\%$). However, these results should be viewed with reserve due to the small sample size of most studies and the considerable heterogeneity. Also, none of the studies reported economic or adverse outcomes. Only one study, with a small sample size, compared different characteristics. This study found that strategies sent to users shortly after they started using the digital intervention and those promoting new digital intervention content were more likely to engage users.

Conclusion

While these results must be interpreted with caution, compared with no strategy, studies reported borderline positive effects of technology-based strategies. More research must be conducted not only to replicate findings, but also to understand which attributes of the strategies are effective in nurturing engagement and how cost-effective they are.

Comments

This paper addressed a very important and mostly ignored issue: how to get participants to show up and complete (“engage with”) digital interventions. These two steps are critical for any program to be successful. We are including this study even though it was based on a review of publications completed by 2013 (therefore lacking more modern technological approaches to engagement) and did not show tremendous results; however, it can serve as a valuable model for future study.

Do health information technology self-management interventions improve glycemic control in medically underserved adults with diabetes? A systematic review and meta-analysis

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Background

This systematic review and meta-analysis analyzed the effect of health information technology (HIT) diabetes self-management education (DSME) interventions on glycemic control in medically underserved patients.

Methods

Five databases were searched using *a priori* protocol. Using the Cochrane Risk of Bias assessment, studies from the database searches were evaluated for quality. Studies were deemed eligible for inclusion in this random effects meta-analysis if they reported either hemoglobin A1c level pre- and postintervention or its change at 6 or 12 months.

Results

Thirteen studies met the criteria for the systematic review, while 10 met the criteria for the meta-analysis. In total, these studies represent data from 3257 adults with diabetes (mean age 55 years; 66% female; 74% racial/ethnic minorities). An unclear risk of bias was detected in most studies ($n = 10$). Interventions used various types of HIT, including cellular/automated telephone ($n = 4$), telemedicine/telehealth ($n = 3$), internet-based ($n = 4$), and computer software without internet ($n = 2$). Pooled A1c reductions were found at 6 months (0.36 [95% CI 0.53, 0.19]; $I^2 = 35.1\%$, $Q = 5.0$), with diminishing effects at 12 months (0.27 [95% CI 0.49, 0.04]; $I^2 = 42.4\%$, $Q = 10.4$).

Conclusion

At 12 months, there are dissipating but significant effects for medically underserved patients with diabetes that achieve glycemic benefit following HIT DSME interventions. The most successful HIT category was telemedicine/telehealth interventions because they integrated interaction with educators, much like in-person DSME programs. When evaluating medically underserved patients, these results show that like in-person, well-designed HIT DSME has the potential to increase access and improve outcomes for this vulnerable group.

Comments

Using meta-analysis of 10 studies, the authors found that individuals who are “medically underserved” did as well with virtually delivered diabetes self-management education as they did with programs delivered in-person. As with all reviews that put the data from different studies together for a new analysis, the results are at best minimal. We include this article because there aren’t enough definitive studies with large enough sample size to make generalizable conclusions. The trends demonstrating impact are in the right direction.

The effectiveness of e- & mHealth interventions to promote physical activity and healthy diets in developing countries: a systematic review

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Int J Behav Nutr Phys Act 2016; **13**: 109

Background

In many developing countries, promoting healthy eating and physical activity is crucial to combat the unprecedented rise in noncommunicable diseases. In these countries, a particularly promising tool is the use of modern information and communication technology. Due to the increased spread of such technologies, they can be used to deliver diet interventions and physical activity. The purpose of this systematic review is to examine the capabilities of electronic and mobile health (e- & mHealth) interventions to encourage healthy diets and physical activity in developing countries.

Methods

Gray literature sources and major databases were searched to find studies that quantitatively investigated the efficacy of e- & mHealth interventions on diet and physical activity outcomes regarding developing countries. Citation alerts and scientific social media were used to retrieve additional studies allowing inclusion until August 2016. The risk of bias of the included studies was assessed using the CONSORT checklist.

Results

Included in the review were 15 studies carried out in 13 developing countries across Europe, Africa, Latin and South America, and Asia. Most studies enrolled healthy adults or adults who were at risk for hypertension or diabetes. The most common delivery channels for intervention were the internet and text messaging, and the average intervention lasted 6.4 months. There was a moderate risk of bias across the studies (with 55.7% of the criteria fulfilled). Significant positive effects of an e- & mHealth intervention on physical activity and/or diet behavior were reported in 11 studies. The interventions were effective in promoting physical activity (50%) and healthy diets (70%).

Conclusion

Most of the studies determined that in developing countries, e- & mHealth interventions were successful in encouraging healthy diets and physical activity. In the future, the interventions should have a more rigorous study design and focus on emerging technologies such as wearable activity trackers and smartphone apps. Also, the cost effectiveness and reach should be investigated.

Comments

While some patients in developing countries have access to all the latest technology, many do not. The near ubiquitous availability of cell phones (some “smart phones”) makes mHealth interventions increasingly valuable in these countries. This review highlights a range of successful interventions from which to learn. These lessons will not only be useful in developing countries, but will also provide tested ideas that can be used in developed

countries relatively inexpensively, and therefore at scale. Developing ways to share these innovations across countries will speed up their adoption. In addition to government and nongovernmental organizations, diabetes companies with worldwide presence could help bring these approaches to the entire world. That is the ultimate promise of the internet and we expect it will happen in the next few years.

The effect of text message support on diabetes self-management in developing countries – a randomised trial

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J Clin Transl Endocrinol 2017; **7**: 33–41

Background

Self-management has the potential to be facilitated through mHealth interventions. In this text messages support for diabetes self-management (TEXT4DSM) study, a mobile phone intervention program was implemented in existing diabetes programs in three low- and middle-income countries (Democratic Republic of Congo, Cambodia, and the Philippines).

Methods

In three different countries, substudies with similar randomized controlled trial designs were carried out. In each substudy 480 diabetic adults were randomized to receive routine care or routine care plus self-management support via text message. The difference between groups in the proportion of subjects with well-controlled diabetes after 2 years was the primary outcome.

Results

For 781 individuals, 2-year HbA1c and baseline measurements were available. The difference in the proportion of subjects with controlled HbA1c was 2.8%, with the intervention group having a slightly higher level of success than the control group after 2 years (making it not statistically significant). After adjusting for baseline HbA1c level, sex, receiving insulin treatment, and participating in the routine program, the logistic regression model showed that the odds ratio for having controlled diabetes after the intervention was

1.1. Over time, the HbA1c dynamics differed between programs, as the number of people with controlled diabetes tended to decrease in Cambodia and increase in DR Congo.

Conclusion

This was the first study that tested the same mHealth intervention in several countries. People should be cautious of their expectations regarding mHealth, as findings showed that text messages didn't show any additional effect on diabetes control. The quality of the routine program, the amount of coverage, and the progression of disease can interfere with the expected effect.

Comments

This is a very well done, 2-year randomized controlled trial using text messaging to augment routine care in 3 low- to middle-income countries. The authors are to be commended for successfully implementing such a challenging and multicountry study. Unfortunately, the addition of text messaging to routine care led to minimal impact. The possible reasons for these negative results are numerous and outlined in the paper. For us, it was particularly noteworthy to read about one trial performed in three different countries with different "routine care" protocols and usage. The finding that text messaging was not impactful could be expected given its relatively targeted and finite "dose effect." The potentially overwhelming challenges in not only providing quality diabetes care, but also in getting participants to adopt and sustain the multiple complex daily behaviors required to improve short- and long-term outcomes. We all need more studies like this one to help us get it right.

The effect of technology-mediated diabetes prevention interventions on weight: a meta-analysis

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J Med Internet Res 2017; **19**: e76

Background

The Diabetes Prevention Program offers lifestyle interventions that target weight loss and decrease the risk of developing type 2 diabetes. Technology-mediated interventions can surmount barriers to program delivery and can disseminate diabetes prevention programs on a wider scale. A meta-

analysis was conducted to assess whether weight loss is affected by such technology-mediated interventions.

Methods

Six databases were searched to identify studies published between January 1, 2002, and August 4, 2016, that reported weight change, used technology to mediate diet and exercise interventions, and which targeted individuals identified as high risk for developing type 2 diabetes.

Results

Out of 1196 acquired citations, 15 studies met the inclusion criteria reporting outcomes for 18 technology-mediated intervention arms with 2774 participants in total. Studies ranged in length from 12 weeks to 2 years. The pooled weight loss effect for the interventions, determined using a random-effects meta-analysis, was 3.76 kilograms (95% CI 2.8, -4.7; $P < 0.001$). Improved glycemic control following the intervention was also reported by a number of studies. It was not possible to determine which technology-mediated intervention method was most efficacious due to the trials' heterogeneity and small sample sizes.

Conclusion

In prediabetic patients, technology-mediated diabetes prevention programs can lead to improvements in glycemia as well as clinically significant weight loss. With their potential for large-scale application, technology-mediated interventions will play an important role in the implementation of diabetes prevention programs.

Comments

While one of the authors of this article (N.K.) was a co-author of this paper, his company's digital diabetes prevention program was not included in the review, so no conflict of interest is present. The study, with all the limitations of any meta-analysis, gives promising directional outcomes indicating that digital DPP programs can have a positive impact on weight loss and presumably diabetes prevention. As the worldwide prevalence of prediabetes and type 2 diabetes increases, more countries are making diabetes prevention a high priority. To reach a population health impact, all modalities of delivery (in-person and virtual) need to be fully utilized. As more purchasers of health-care services (governments, health plans, employers, etc.) agree to cover the prevention of type 2 diabetes, the current worldwide emphasis on diabetes prevention may well transform from vision to reality.

Web-based interventions for weight loss or weight loss maintenance in overweight and obese people: a systematic review of systematic reviews

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J Med Internet Res 2017; **19**: e229

Background

Weight loss and weight loss maintenance are challenging for both patients and providers. Web-based programs allow for the potential delivery of interventions to address both of these issues, though the exact impact of these programs is still uncertain. The aim of this meta-systematic review was to provide a complete summary of the effectiveness of web-based interventions targeting weight loss and weight loss maintenance.

Methods

Electronic databases were searched to identify meta-analyses and systematic reviews containing at least one study that examined the success of a web-based intervention on weight loss and/or weight loss maintenance among overweight and/or obese participants. Twenty of the reviews met the inclusion criteria and were assessed for methodological quality using the Revised Assessment of Multiple Systematic Reviews (R-AMSTAR). All reviews netting a R-AMSTAR score ≥ 22 were deemed sufficient, and key methodological and outcome data were extracted.

Results

The results showed that web-based programs for both weight loss and weight loss maintenance were more successful than minimal or controlled conditions. However, when web-based programs and similar non-web-based interventions were compared, the results were less consistent.

Conclusion

While further studies are needed to better understand the performance of both types of web-based programs, the results from the weight loss maintenance intervention were more successful than those from the weight loss intervention.

Comments

This review of reviews focused on the impact of digital programs on weight loss and weight loss maintenance. While the results were promising, the web-based programs seemed to be less effective than comparable non-web-based interventions. Unfortunately, there were no studies with effective head-to-head competition—not that such a study could be easily conducted. One issue with any comparison experiment would be the fundamental question of selection bias. For example, assume the study had a large enough sample size with randomization. The key issue would then be whether randomization was done before or after assignment to the web-based or non-web-based program. Real-world assignment would most likely include patient choice of

delivery mode based on their personal preference (e.g., in-person or digital) and logistical issues (e.g., travel time to the weekly program or access to the internet). However, this would markedly increase the impact of selection bias making the results more difficult to interpret.

Outcomes of a digital health program with human coaching for diabetes risk reduction in a Medicare population

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Background

The prevention of type 2 diabetes is possible when at-risk individuals are provided a structured, year-long, in-person intervention proven effective in the National Institutes of Health-funded Diabetes Prevention Program (DPP) published in 2001. The objective of this study was to examine the outcomes of a Medicare population who participated in a program combining a digital DPP with human coaching for diabetes risk reduction.

Methods

Those at risk for diabetes enrolled in a program that combined human coaching and digital health. Health outcomes and participation were examined at 16 weeks, 6 months, and 12 months.

Results

There was a total of 501 enrolled participants. Of those in this population who completed 4 lessons, 92% completed at least 9 of the 16 core lessons. On average, enrollees participated in 19 of 31 possible opportunities for weekly program engagement. At the end of the one year, participants lost 7.5% (SD=7.8%) of initial body weight. Glucose control improved among enrollees with clinical data (HbA1c change -0.14% ; $P=0.001$) and levels of total cholesterol went down (-7.08 mg/dL; $P=0.008$). Improvements were seen in self-reported depression, well-being, and self-care ($P<0.0001$).

Conclusions

This Medicare population demonstrated continuous program engagement and improvements in weight, health, and well-being. The results support digital interventions in conjunction with human coaching for reducing the risks associated with chronic disease among older adults.

Comments

One of the authors (N.K.) has a conflict with this paper (his company sells a competitive digital DPP intervention), so no review of the article will be completed.

Diabetes self-management training in a virtual environment

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Diabetes Educ 2017; **43**: 413–421

Background

While diabetes self-management training (DSMT) improves diabetes health outcomes, most patients do not participate. Virtual environments (VEs) could bring DSMT to a wider audience.

Methods

This paper describes the experience of diabetes educators and health professionals working to establish and teach DSMT in Diabetes LIVE (Learning in Virtual Environments), a VE, as well as the implications for future use of VEs in DSMT.

Results

Providing DSMT in a VE was found to be effective and can preserve real-time interaction between patients and educators. This approach could overcome barriers to reaching patients. Challenges include overcoming technological barriers, patient recruitment challenges, and improving comfort levels of educators and patients to the functionality of the VE.

Conclusions

VEs may become powerful tools for diabetes and other health educators to reach patients. Studies are needed to demonstrate their impact as well as costs and benefits.

Comments

The authors describe a “virtual environment” in which patients with diabetes can learn specific skills for how to better manage their diabetes. As this paper is only a description of the environment, time will tell—and subsequent papers will describe—whether this approach works and can get people engaged in their health. The potential is promising, but the jury is still out.

Guidelines for the gamification of self-management of chronic illnesses: multimethod study

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JMIR Serious Games 2017; **5**: e12

Background

Gamification, the use of game elements and techniques in nongaming contexts, is increasingly being used in health-care and is receiving a large amount of attention in both the industry and academic research. Despite this rise in popularity, though, it should be noted that many gamification apps in health-care do not follow any standardized guidelines. This research aims to propose guidelines based on the validated framework of the Wheel of Sukr and to assess these guidelines through focus group sessions with developers and expert interviews. The 8 elements of the model include (1) socializing, (2) self-representation, (3) fun, (4) esteem, (5) growth, (6) sustainability, (7) motivation, and (8) self-management.

Methods

Expert interviews (n=6) were carried out to determine the content of the guidelines and whether they reflect the Wheel of Sukr. The guidelines were also assessed by developers (n=15) in 5 focus group sessions, each of which had an average of 3 developers.

Results

Experts agreed that the guidelines reflect the framework of the Wheel of Sukr and that developers can possibly use these guidelines to create gamified self-management apps for chronic illnesses. Developers welcomed these guidelines and found them to be useful, clear, and implementable. When presented with nongamified self-management apps, the developers also proposed numerous ways for gamifying these programs.

Conclusions

The findings convey that the guidelines introduced in this research were valuable, clear, and ready to be applied for the creation of self-management apps that use gamification as described in the Wheel of Sukr. The guidelines are now ready for practical testing, and further practical studies regarding the efficacy of each component will be carried out.

Comments

This study outlines the key elements that should be included in the use of gamification for self-management support for patients with chronic diseases (such as diabetes). The thoughtful approach should serve as an example of how to create digital interventions with new technology for which in-person interventions cannot be used as the base. These gamification guidelines use evidence from a variety of self-management support interventions and transform them for the modern technology environment. The challenge will be to stay true to the guidelines when creating programs that not only impact self-management, but also will be used by the target population. Time will tell if this will be successful in a research environment, and will eventually be able to produce successful results at scale using a suitable commercial approach.

Final Remarks

This article is our annual attempt to demonstrate that the field of digital interventions to prevent and treat diabetes is robust and progressing. While specific programs are advancing and being adopted, most of them are still in the “pilot” or “limited deployment” stage. Part of the reason for this slow adoption is that it takes time to successfully bring new approaches to the fractured and uncertain marketplace we call health-care. Another reason is the slow pace of academia and industry in transforming interventions into effective, patient-centered digital programs and proving their effectiveness.

But the key reason is the lack of business models that allow providers of these life-transforming interventions to get a fair rate of return on their investment. Compare the slow pace of adoption of clinically linked, technology-enabled self-management support interventions to the rapid pace of adoption of consumer-focused products such as eBooks, cell phones, social media platforms, etc. Given the public’s reluctance to pay for health-care related services and support, adoption is slowed. The payer for health-care (e.g., government, health plans, health-care providers, employers) must (1) decide what level of evidence is required to justify paying for the service, (2) agree to cover the cost of the intervention, and (3) figure out how to get the program to the end user—the patient.

All of this may change with more consumers assuming risk for larger portions of their health-care expenses. Will we see patients paying for behavior change interventions? Will they pay for these services as a way to decrease their out-of-pocket health-care-related costs and as a way to keep themselves healthy? Products linked to health-care paid for by consumers are at a distinct disadvantage compared with direct-to-consumer approaches, due to added expenses and additional administrative burdens. Clinically linked programs need to demonstrate compliance with a variety of laws and policies such as strict privacy regulations, fidelity to the evidence-base on which it is built, and restrictions on marketing, while direct-to-consumer approaches will have far less restrictive requirements. These added requirements make the rapid evolution of clinically linked interventions quite difficult.

It is our hope that there will be enough financial and other supports to allow evidence-based and proven-effective programs to not only do *good*, but also do *well* for the companies which deploy them.

Author Disclosure Statement

Neal Kaufman is the owner of Canary Health; spouse is an employee of Medtronic.

Maryam Dadashi has no conflict of interest.