



mHealth prompts within diabetes prevention programs: a scoping review

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Background: Mobile health (mHealth) prompts (e.g., text messaging, push notifications) are a commonly used technique within behaviour change interventions to prompt or cue a specific behaviour. Such prompts are being increasingly integrated into diabetes prevention programs (DPPs). While mHealth prompts provide a convenient and cost-effective way to reinforce behaviour change, no reviews to date have examined mHealth prompt use within DPPs. This scoping review aims to: (I) understand how mHealth prompts are being used within behaviour change interventions for individuals at risk for developing type 2 diabetes (T2D); and (II) provide recommendations for future mHealth prompt research, design, and application.

Methods: The scoping review methodology outlined by Arksey and O'Malley were followed. Medline, CINAHL, PsycInfo, Web of Science, and SportDiscus were searched. The search strategy combined keywords relating to T2D risk and mHealth prompts in conjunction with database-controlled vocabulary when available (e.g., MeSH for Medline).

Results: Of the 4,325 publications screened, 44 publications (based on 33 studies) met the inclusion criteria and were included for data extraction. Text messaging was the most widely used mHealth prompt (73%) followed by push notifications (21%). Only 30% of studies discussed the theoretical basis for prompt content and time of day messages were sent, and only 27% provided justification for prompt timing and frequency. Fourteen studies assessed participant satisfaction with mHealth prompts of which only two reported dissatisfaction due to either prompting frequency (hourly) or message content (solely focused on weight). Nine studies assessed behavioural outcomes including weight loss, physical activity, and diabetes incidence, and found mixed effects overall.

Conclusions: While mHealth prompts were well-received by participants, there are mixed effects on the influence of mHealth prompts on behavioural outcomes and diabetes incidence. More thorough reporting of prompt content development and delivery is needed, and more experimental research is needed to identify optimal content, delivery characteristics, and impact on behavioural and clinical outcomes.

Keywords: Prediabetic state; text messaging; push notifications; telecommunications; preventive health services

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Introduction

Type 2 diabetes (T2D) is a growing public health concern due to the devastating impact it has on the individual diagnosed, and the associated economic costs (1). T2D affects an individual's quality of life (2), leads to increased depression and anxiety (3-5), and is among the leading causes of cardiovascular disease, blindness, kidney failure, and lower limb amputations (6). In 2017, T2D was ranked as the ninth leading cause of death worldwide with greater than one million deaths attributed to T2D, and the seventh leading cause of disability and suffering as measured by disability-adjusted life years (DALYs) (7). Despite the substantial investments made in clinical care, public health initiatives, and research, T2D prevalence and burden continue to increase (7). A considerable body of research has shown that up to 60% of T2D cases can be prevented through structured dietary and physical activity (PA) programs (8-11); however, when translated into public health initiatives, the effects of such diabetes prevention programs (DPPs) are diluted (12). This is likely because translational studies have not considered the adaptability and scalability needed for public health interventions resulting in inequitable access to such programs (13). Rates of T2D are higher among individuals with lower income and education levels, those who are unemployed, and certain ethnic minorities (14-16). Additionally, these individuals at highest risk must also overcome other barriers to accessing healthcare systems to prevent and manage T2D, such as language barriers, lack of culturally tailored information, and the cost associated with treatments (16,17). Given the increasing prevalence of T2D, lack of scalable community based DPPs, and inequitable access to healthcare resources, there is a need for diabetes prevention programming that can provide care to assist those at highest T2D risk.

In 2020, it was noted that approximately 85% of the global population was covered by a 4G network, with 93% of the world having access to a mobile-broadband network (i.e., access to wireless internet via a mobile device) (18). Further, health-related technological development is at an all-time high (19,20). This rapid adoption of technology and wide acceptability of remotely delivered health-related programs has shifted diabetes programming towards electronic and mobile health (eHealth and mHealth respectively) solutions as a way to augment DPPs and improve access to care. In the past five years, there have been a host of reviews discussing eHealth and mHealth DPPs and the use of different technologies to amplify in-

person DPP delivery (21-26). Meta-analyses of DPPs incorporating eHealth and mHealth components report clinically significant weight loss (23,27) which is comparable to reviews of solely in-person DPPs within the community which report an average weight loss of 3-5% (28,29).

For example, Bian and colleagues (27) conducted a systematic review and meta-analysis of 18 mHealth mediated DPPs. Meta-analyses on weight outcomes found that mHealth mediated DPPs lead to clinically significant weight loss of 4.46% (a mean 3.75 kg weight loss) in those at risk for developing T2D. Further, they found that eight of the 18 intervention arms included in their review reported sustained weight loss for one or more years post intervention. Similarly, Joiner and colleagues (23) conducted a systematic review and meta-analysis of 22 DPPs which were either delivered as fully mHealth or included mHealth components. At the interventions' final timepoints, mHealth (and mHealth augmented) DPPs result in mean weight loss of 3.98%. Further, interventions were sorted based on the provision of behavioural supports into three categories: (I) stand-alone interventions in which participants were not offered ongoing support from a counsellor; (II) remote support in which participants were provided with behavioural support via mHealth technologies (e.g., online messaging communications, emails, text messaging prompts, video conferencing or phone calls with a counsellor); and (III) in-person support in which participants received support from a counsellor face-to-face. Authors found that stand-alone interventions had an associated weight loss of 3.43%, remote support interventions had an associated weight loss of 4.31% and in-person support resulted in an associated weight loss of 4.65%. Based on these results, authors concluded that behavioural support (through mHealth or in-person communication) from a diabetes prevention counsellor is an important aspect of mHealth DPP delivery.

Despite promising results from mHealth and mHealth augmented DPPs, authors consistently report heterogeneity in what digital components are being used (e.g., DVDs, web-based interventions, mobile phone applications, text messaging, etc.) and state that future research should focus on ways to optimize behavioral supports (22,23). One way to improve the efficiency and effectiveness of DPPs is to understand how to best integrate specific mHealth components. By breaking down behavioural supports offered by DPPs into individual behaviour change techniques (BCTs), researchers can delineate which components are most impactful within these interventions

(e.g., self-monitoring of diet and PA behaviours), and how to best administer those components (e.g., optimal timing to send a notification to prompt self-monitoring). Understanding which digitally delivered BCTs in DPPs lead to clinically meaningful changes in T2D risk reduction can aid in more cost efficient, effective, and scalable DPP development and implementation.

BCTs

BCTs are the smallest “active ingredients” within a behaviour change intervention which can be easily observed and replicated (30). Michie and colleagues BCTs taxonomy v1 (BCTTv1) (30) provides researchers with a list of 93 BCTs grouped into 16 distinct BCT categories. For both in-person and mHealth DPPs, self-regulatory techniques (e.g., goal setting, self-monitoring, action planning, problem solving) have been recommended as effective components to improve intervention efficacy (25,31). In addition to self-regulatory BCTs, use of the BCT *prompts/cues* is commonly cited within effective mHealth behaviour change interventions (25,32-35).

mHealth prompts

As per Michie and colleagues, the BCT “prompt” is defined as the introduction of an environmental or social stimulus with the purpose of prompting or cueing a target behaviour (e.g., a sticky note on door reminding you to take the stairs) (30). Prompts are one of the most frequently cited BCTs within mHealth PA, weight loss, and DPP reviews (25,32-35) and mHealth prompts (e.g., text messaging, push notifications) are one of the most commonly cited program components within mHealth DPPs (23,27).

mHealth prompts are a convenient and cost-effective way to reinforce behaviour change (36,37) and have been shown to improve self-monitoring and adherence to PA goals (38,39). Further, there is a growing body of evidence to support the use of mHealth prompts within behaviour change interventions (40-45). For example, Whittemore and colleagues published an umbrella review to synthesize evidence from nine existing systematic reviews (representing 72 unique studies) assessing effectiveness of text messaging prompts for adults with T2D on haemoglobin A1c (HbA1c). Five of the included reviews conducted meta-analyses examining the impact text messaging has on HbA1c and found clinically and statistically significant results ranging from -0.38% (95% CI: -0.53 to -0.23; $P < 0.01$) to -0.8%

(95% CI: -1.1 to -0.5; $P < 0.01$). Moderator analyses within these reviews highlighted that adults with more recent T2D diagnoses (<7 years) and lower baseline HbA1c have better outcomes associated with the text messaging programs. Providing early intervention via text messaging upon T2D diagnosis (or perhaps even when a diagnosis of prediabetes—the precursor to T2D—is made) may therefore optimize improvements in HbA1c. Despite this notion, no reviews to date have examined the use of mHealth prompts within DPPs. A summary paper which synthesizes what is currently known about mHealth prompts within DPPs is an important step towards understanding how to optimally develop and deliver effective digital interventions to improve diabetes prevention outcomes. Therefore, the purpose of this scoping review was to identify and describe the ways in which DPPs are using mHealth prompts. We present the following article in accordance with the PRISMA-ScR reporting checklist (available at <https://mhealth.amegroups.com/article/view/10.21037/mhealth-21-22/rc>) (46).

Methods

A scoping review was conducted using Arksey and O'Malley's methodological framework for scoping reviews (47) which was further refined by Levac *et al.* (48) and Daudt *et al.* (49). To improve the methodological rigour of this study, we also used the Preferred Reporting Items for Systematic Reviews and Meta-Analysis extension for Scoping Reviews (PRISMA-ScR) checklist (46) and the PRISMA diagram was used to delineate key methodological processes (see *Figure 1*). The protocol for this review was published on Open Science Framework (available at <https://doi.org/10.17605/OSF.IO/XJHWN>).

Identify the research question

The current review aims to provide an overview on how mHealth prompts are used in diet and PA interventions targeting T2D risk reduction. Specifically, we aim to answer the following questions: (I) what were the behavioural targets of mHealth prompts; (II) how was content developed (what theoretical basis is identified); and (III) how were prompts delivered (who delivered them, how long prompts were received for, what time prompts were sent, and how frequently prompts were sent) within DPPs?

In order for an mHealth prompt to act as a mechanism of action as defined by Michie (30), mHealth prompts were operationalized as any web-or mobile phone-based

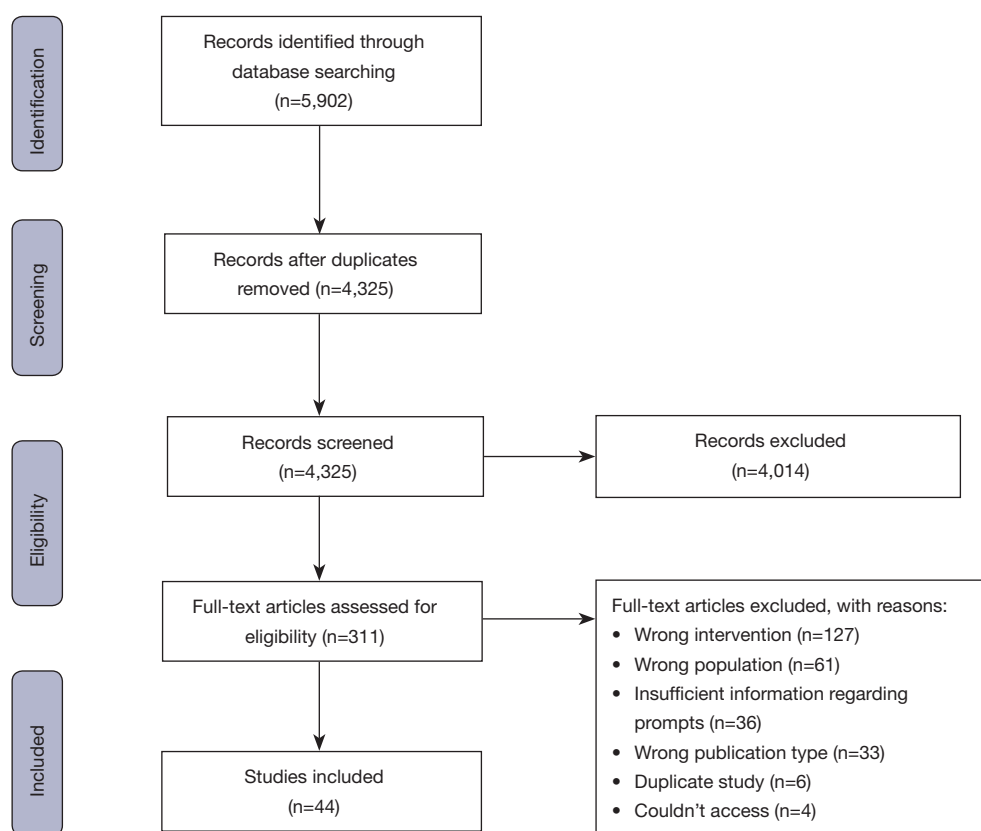


Figure 1 PRISMA flow diagram.

communication in which individuals receive a written “notification” (e.g., text messages or push notifications) on the home screen of their device without needing to take action first (i.e., if a participant is required to log into a program-related app or website in order to be prompted, that would make the cue to action obsolete). This definition excluded in-app messaging and emails unless it was stated that participants were required to have notifications turned on for these applications for the duration of the study. This ensures they will receive the prompt regardless of whether the participant is engaging with program related mobile phone or web-apps.

Identify relevant studies

Medline, CINAHL, PsycInfo, Web of Science, and SportDiscus were searched for studies relating to DPPs and mHealth prompts. Databases were searched from inception until November 2020. The search strategy combined keywords relating to T2D risk and mHealth prompts in conjunction with database-controlled vocabulary when

available (e.g., MeSH for Medline). The search strategy was reviewed by a health sciences librarian. A list of search terms and the full Medline search strategy can be found in [Appendix 1](#). Truncation symbols and wildcards were used to allow for search term variations.

Inclusion

To be included in the review, the article had to refer to the use of mHealth prompts as a piece of an intervention or as the sole intervention targeting diabetes risk reduction through diet and/or PA behaviour change. Additionally, only studies conducted with an adult population (>18 years old) identified as “at risk” for developing T2D were included. Only published studies written in English were included.

Exclusion

Studies were excluded if it was stated that messages were sent to participants from an app but did not indicate that they were pushed to the home screen of a participant’s device, or if the intervention stated it used an mHealth prompt but provided no further information about the

prompts (e.g., number of prompts sent, timing of prompts, etc.). No limitations on date, geographical location, study design, or duration were imposed.

Study screening and selection

All studies obtained from the identified databases were uploaded to Covidence (Veritas Health Innovation Ltd., Melbourne, Australia), a software used to streamline the review process (50). Duplicate publications were automatically removed with all screening and subsequent data extraction taking place on the Covidence platform. Two reviewers (MM and KM) piloted then refined the screening guidelines on the first 100 articles, then independently screened the remaining 4,225 titles and abstracts. The same reviewers then screened the 310 studies included in the full-text screening resulting in 44 studies included in the final review (see *Figure 1*). Any conflicts during the screening were resolved during a consensus meeting between the reviewers.

Charting and extracting the data

A custom data extraction form was developed to obtain general study information (author, title, study location, design); participant information (gender, sex, age, ethnicity); and a description of the mHealth prompts used in the study (mode of delivery, content, theoretical basis, timing, frequency). When multiple publications pertained to a single study, they were considered together for complete data extraction. The data extraction form was piloted on five randomly selected publications by two authors (MM and KM) to ensure consistency. Information was then narratively summarized.

Results

Title and abstract screening guidelines were piloted and refined on the first 100 publications (resulted in eight conflicts). The remaining title and abstract screening resulted in 96% agreement (Cohen's kappa =0.70) indicating substantial agreement. Full-text screening resulted in 93% agreement (Cohen's kappa =0.73), again indicating substantial agreement. A total of 44 publications (based on 33 studies) met the eligibility criteria. Of those included studies, 11 (33%) were stand-alone mHealth prompt interventions and 22 (66%) included prompts as a component within a larger DPP. The 33 studies took place

in the following locations: USA (n=14), India (n=4), UK (n=3), Australia (n=3), China (n=3), Finland (n=1), Canada (n=1), Saudi Arabia (n=1), Spain (n=1), Africa (n=1), and one study took place in two countries (India and UK). Of the 44 publications, almost three quarters (n=32; 73%) were published in the past 5 years [2016–2021].

mHealth prompt content

Twenty-five studies included prompts which focused on both diet and PA behaviour change. The remaining studies described prompts targeting PA only (51–54), diet only (55) or no health behaviour targets within the prompts (prompts were intended to direct participants to an associated platform to view program content) (56,57). Prompt content was tailored to broad groups or populations in five studies based on the religion (58) or culture (59–62) of the target groups. An additional 13 studies tailored the prompt content to individual participants based on their goals (55,63,64), previous behaviours (51,52,65–68), T2D risk level (69), or stage of change (70–72). Additional information pertaining to prompting content can be found in *Table 1*.

Development

The majority of studies did not provide detailed information on how prompt content was developed (n=18; 55%). Of those that did provide information, content was generally written by a team of experts (including researchers, diabetes experts, nurses, community and patient advisory boards, etc.) and based on previous literature or recommendations put forth by health authorities (52,54,60,61,70,72–75). Seven studies (21%) took an additional step following message creation and had key stakeholders review the messages to allow for iterative development and refinement (52,59–61,65,73,76). For example, O'Reilly and Laws (76) conducted a focus group in which participants ranked messages using traffic light stickers (green, message is useful; orange, unsure; red, message is not acceptable) followed by a discussion to identify how to improve those messages which were rated as not acceptable.

Morton and colleagues (52) went beyond these two broad phases of creation and refinement of messages and used a four-phase process to develop prompt content. Phase 1 included conceptualization of the prompts through a literature review, development of intervention objectives, and identification of BCTs. Phase 2 involved informal discussions and focus groups to explore whether text messaging prompts are acceptable. Phase 3 involved formal

Table 1 Information pertaining to mHealth prompt content

Reference	Behaviour target	Intention of prompt	Theory	Content development	Example message
Berkley-Patton <i>et al.</i> , [2020]	Diet & PA	Provision of information/ Encouraging behaviour change	Not specified	Not specified	“Hello Brothers and Sisters! What are you about to put into your temple? Remember to limit the amount of sugar and fat that you consume”
Polgreen <i>et al.</i> , [2018]	PA	Reminders to wear Fitbit; feedback on previous days behaviours; and goal setting reminders	Not specified	Not specified	“Remember to wear your Fitbit! What is your goal for today?”
Gupta <i>et al.</i> , [2019]; Tewari <i>et al.</i> , [2020]; Shanthosh <i>et al.</i> , [2020]	Diet & PA	Improve motivation and provide remote on-going support	COM-B model	Not specified	None provided
Cheung <i>et al.</i> , [2019]	Diet, PA, & newborn health	Provision of advice, motivation, information and support to overcome barriers to behaviour change & personalized weekly step target messages	Not specified	Based on existing messages from previous trials. Additional messages developed by experts in diabetes, nutrition, physical activity, health promotion, and lactation. Messages reviewed for readability then assessed/ refined based on participant feedback	“Small steps count! Just 10 min sessions count towards your target of 30 mins per day. Keep active!”
Nanditha <i>et al.</i> , [2020]; Thomson <i>et al.</i> , [2018]	Diet & PA	Provision of motivational and educational messages; goal setting and self-monitoring reminders	Trans-theoretical model	Based on previous work. In the UK a Patient and Public Involvement Group provided input on the prompt design and content	None provided
Ram <i>et al.</i> , [2014]; Ramachandran <i>et al.</i> , [2013]; Nanditha <i>et al.</i> , [2018]	Diet & PA	Provision of information (healthy lifestyle, benefits of PA and diet); how to start PA and diet practices; strategies to avoid relapse and maintain motivation	Trans-theoretical model	Based on the transtheoretical model stages	“Physical activity helps to maintain normal blood sugar and blood pressure”
Wong <i>et al.</i> , [2013]; Wong <i>et al.</i> , [2016]; Wong <i>et al.</i> , [2018]	Diet & PA	Provision of information (diabetes/prediabetes, lifestyle modifications); social norms (how others will appreciate the lifestyle modifications); self-efficacy enhancing messages (how to control your behaviours)	Theory of planned behaviour and Social Cognitive Theory	Written by expert team including doctors, nurses and dietitians and mapped onto the Theory of Planned Behaviour and Social Cognitive Theory	“Diabetic complications include eye problems and feet problems”
Catley <i>et al.</i> , [2019]; Catley <i>et al.</i> , [2020]	Diet & PA	Reinforce session content, increase motivation, support implementation planning enhance self-efficacy, and provide positive affirmations	Not specified	Written with input from community advisory board	“Stand for a period of time at home instead of sitting; this does not require much energy or time”

Table 1 (continued)

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Reference	Behaviour target	Intention of prompt	Theory	Content development	Example message
Block <i>et al.</i> , [2015a]; Block <i>et al.</i> , [2015b]	Diet & PA	Prompt goal setting (emails); reinforce goals and encourage program engagement (push notifications). Participants could also message each other with pre-drafted motivational messages	Learning theory and habit formation	Not specified	“Studies show that people who eat a good breakfast are less likely to overeat later in the day”
Buis <i>et al.</i> , [2013a]; Buis <i>et al.</i> , [2013b]	Diet & PA	Risk assessment; provision of information; promotion of behaviour change	Not specified	Not specified	None provided
Ritchie <i>et al.</i> , [2020]; Fischer <i>et al.</i> , [2016]; Fischer <i>et al.</i> , [2019]	Diet & PA	Prompting self-reported weight; skill teaching (tracking calories or fat); problem solving (relapses and eating around the holidays); motivation; stress reduction; recipes; links to additional resources; PA promotion messages	Not specified	Based on the NDPP curriculum and refined with input from patients with prediabetes through 6 focus groups (3 in English, 3 in Spanish)	None provided
Morton <i>et al.</i> , [2015]; Yates <i>et al.</i> , [2015]	PA	Prompting self-reported PA; feedback; motivational/habit formation; informational; problem solving; attitudes/beliefs; self-efficacy & self-regulation of PA behaviours	Control theory and BCTs	Phase 1 conceptualization (literature review, identify BCTs); Phase 2 formative research (understand context/acceptability of SMS); Phase 3 pre-testing (focus groups; explore specific SMS content, types and regimens); Phase 4 piloting (pilot study to resolve technical issues; interviews to explore user experiences)	“Please text in your weekly step count by entering the number of steps you have achieved in total over the past 7 days”
Everett <i>et al.</i> , [2018]	Diet & PA	Personalized push notifications adapted based on actual life habits and sent to users, providing an actionable recommendation to prompt behaviour change	Not specified	Machine learning. Mobile phone data used to provide personalized, contextual, just-in-time, just-in-place recommendations	“Hi Hans, you have 15 min of activity left. The sun is shining so let's pick up coffee from Mister... and achieve your daily continuity goal”
Tkatch <i>et al.</i> , [2018]	Diet	Provision of information (e.g., recipes); prompts to send another participant a “high 5”; support users accountability, commitment and engagement with program	Not specified	Not specified	None provided

Table 1 (continued)

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Reference	Behaviour target	Intention of prompt	Theory	Content development	Example message
Limaye <i>et al.</i> , [2017]	Diet & PA	Promote healthy lifestyle behaviours through educational and persuasive messages	Not specified	Not specified	"Foods like Chocolates, Pastries, Sweets, Sago, Potato, Soft drinks, Alcohol etc. directly influence blood sugar levels. Stay away from such foods!"
Pfammatter <i>et al.</i> , [2016]	Diet & PA	Provision of information (causes and complications of diabetes); motivate improvement in diabetes risk behaviours	Not specified	Written by Emory University and reviewed by a Behavior Change Task Force	"Diabetes is a huge problem. At least 5 crore people in India live with diabetes. Diabetes kills 10 lakh Indians each year. Arogya World"
Fukuoka <i>et al.</i> , [2015]	Diet & PA	Reminders to self-monitor	Not specified	Not specified	"Have you let everyone around you know that you are trying to become more active so they can help you meet your goal?"
Abebe <i>et al.</i> , [2013]	Diet & PA	Provision of education (diet/PA tips, local healthcare providers/resources); progress tracking. Messages aimed to be culturally competent, reflecting an understanding of local interpretations of disease and the colloquial language used	Health Belief Model	Written by advisory group (community members, research teams, mHealth vendor, Centers for Disease Control and Prevention, and the American Diabetes Association). Content based on evidence-based guidelines. Focus groups held to refine messages and ensure their relevance and cultural competence	"Some people call diabetes sugar or touch of sugar. Don't be fooled, diabetes is very serious, no matter what you call it"
González <i>et al.</i> , [2013]	Diet & PA	Notifications are sent to patients under the following conditions: too infrequent access to the platform, failure to upload enough heart rate monitor data, too infrequent entry of food intake data, exceeding the prescribed caloric intake, not reaching the prescribed caloric expenditure, and successfully following the prescribed therapy	Not specified	Not specified	None provided
Fukuoka <i>et al.</i> , [2011]	N/A	Participants want tailored messages to address individual weaknesses	Not specified	N/A	N/A

Table 1 (continued)

Table 1 (continued)

Reference	Behaviour target	Intention of prompt	Theory	Content development	Example message
Alzeidan <i>et al.</i> , [2019]	Diet & PA	Provision of education (healthy lifestyle, benefits of PA and a healthy diet). Every third message includes a summary of information covered in previous messages	Trans-theoretical model	Based on WHO and Saudi National Diabetes Prevention and Control Program resources. Messages written to map onto transtheoretical model. Messages will undergo refinement by public health/mental health specialist, a language reviser, and target population	None provided
Rosas <i>et al.</i> , [2018]	Diet & PA	Reminders (attend sessions, watch videos, use written materials, self-monitor, reach out to coach with questions); provision of information (maintenance topics)	Not specified	Not specified	None provided
Kim <i>et al.</i> , [2019]	None	Prompt individuals to go to their homepage to view a health message	Not specified	Not specified	None provided
Whelan <i>et al.</i> , [2019]	PA	Motivational messages and reminders to move	Not specified	Not specified	None provided
MacPherson <i>et al.</i> , [2019]	PA	Prompt self-monitoring, verbal persuasion, and performance accomplishment	Social Cognitive Theory	Based on constructs within Social Cognitive Theory and based on previous research	“Hey (insert name). I have been watching your progress for the last few weeks and wanted to say congratulations on what an awesome job you have been doing! You should be really proud of yourself—you’ve been sticking with your exercise plan over the past month! Keep up this fantastic effort and I’ll be right here watching your fabulous achievements”
O’Reilly <i>et al.</i> , [2019]	Diet & PA	Provision of information (screening, risk assessment, use of trackers, fibre); health coaching; goal setting; reminders to watch storytelling video	Not specified	Focus groups where participants ranked content using traffic light coloured stickers (red = not acceptable, orange = unsure, and green = acceptable). Following ranking activity, messages were grouped by colour and discussed to improve content	“Hi [mother’s name], I am Magda and I would like to volunteer to be your own personal health coach. Making changes to your lifestyle can improve your whole family’s health as well as your own. I have a series of 7 topics that we can work through together that can help you make changes at a pace that suits you and your busy schedule. Click/tap here to read our first topic”

Table 1 (continued)

Table 1 (continued)

Reference	Behaviour target	Intention of prompt	Theory	Content development	Example message
Staite <i>et al.</i> , [2020]	Diet & PA	Provision of information and encouragement of lifestyle changes; feedback on behaviours; respond to user messages	Not specified	Written based on tenets of motivational interviewing	“Think about how many staircases you might be able to use today instead of the lift”
Ho <i>et al.</i> , [2020]	Diet & PA	Provision of education (general information about prediabetes, T2D, and lifestyle modification)	Not specified	Not specified	None provided
Srivastava <i>et al.</i> , [2019]	Diet & PA	Reminders and encouragement	Not specified	Not specified	“Keep up the good work using your Type II Diabetes Prevention module!”
Xu <i>et al.</i> , [2020]	Diet & PA	Motivate users; provision of information (materials arranged into comics, stories, or short articles); provision of health assessments (e.g., food frequency questionnaire)	Trans-theoretical model	Not specified	None provided
Rollo <i>et al.</i> , [2020]	Diet & PA	Motivational and supportive messages and reminders to self-monitor and reflect on goals	Not specified	Not specified	“[First name], when cravings hit, have a glass of water and wait a few mins. You may be confusing thirst for hunger. The craving may fade once you have rehydrated”
Sinclair <i>et al.</i> , [2020]	Diet & PA	Appointment reminders and text messages reinforce and encouraging healthy eating and physical activity	Not specified	Not specified	None provided
Harjumaa <i>et al.</i> , [2020]	None	Reminders to use the system (when user was not logged in; user had not made any selections; user but had not reported selections; user had not used the app for a week)	Not specified	Not specified	None provided

PA, physical activity; BCT, behaviour change technique.

pre-testing through use of a think-aloud protocol to gauge participants reactions to specific prompt content. Lastly, Phase 4 involved piloting the prompts then concluded with brief interviews to explore participants opinions relating to the acceptability and feasibility of prompt content and regimens.

Theoretical background

Ten studies (30%) mention the use of a theory, model, or framework in relation to prompt content development. In

all, seven theories or models were identified: four studies cited the Transtheoretical Model (62,70-72), two cited Social Cognitive Theory (54,74) [one of which also used the Theory of Planned Behaviour (74)], one cited the COM-B Model (65), one cited Learning Theory (63), one cited Control Theory (52), and one cited Health Belief Model (61). An additional four studies discussed theory use in the intervention as a whole, but did not specify how this theory informed the development of the prompts (57,77-79). These studies used Social Cognitive Theory

(57,77,79) and the Theory of Planned Behaviour (78). Only six studies provided detailed explanations of how the theories were used to inform the prompt content (52,61,70-72,74) corresponding to four theories: the Transtheoretical Model, Social Cognitive Theory, the Health Belief Model, and Control Theory which are described below.

The Transtheoretical Model

The Transtheoretical Model posits that behaviour change occurs in a series of stages: precontemplation, contemplation, preparation, action, and maintenance (80). In three studies (70-72) prompt content was developed to map onto the different stages within the Transtheoretical Model and participants were assigned to receive prompts corresponding to the stage they were currently in.

Social Cognitive Theory

Social Cognitive Theory was used to inform the content of Wong and colleagues prompts (74) with a specific focus on participant's self-efficacy, or their beliefs in their own capabilities to perform a behaviour. Specifically, self-management goals were a primary focus of the prompt content to target self-efficacy.

Health Belief Model

Abebe (61) found that individuals within the community they were targeting were indifferent towards their own T2D risk factors and lacked knowledge regarding how different risk factors influence T2D onset. As such, the research and advisory group created educational prompt content based on the Health Belief Model in which participants susceptibility to diabetes and the potential consequences of developing T2D were emphasized. These prompts also provided simple steps to reduce risk and the short- and long-term benefits of taking those steps.

Control Theory

Control Theory was identified in Phase 1 of Morton and colleagues (52) four-phase iterative development process. Authors postulate that strategies within Control theory, including goal setting, self-monitoring, feedback on and review of goals, are central to self-management of diabetes risk reduction behaviours. These strategies resulted in authors selecting specific BCTs using the CALO-RE taxonomy (81). The key BCTs that were chosen for this study and mapped onto Control Theory include goal setting (behaviour), action planning, self-monitoring, goal review,

problem-solving, and social support.

mHealth prompt delivery

mHealth prompts were most commonly delivered via text messaging (n=24, 73%), followed by push notifications (n=7, 21%). Of the remaining two studies, one used both text messaging and push notifications (82) and one did not specify mode of prompt delivery (83). Prompts were commonly sent through an automated system (n=13, 40%) or by a coach or healthcare provider (n=7, 21%). Eleven studies (33%) reported two-way prompting in which the coaches and participants could both send messages, nine (27%) were one-way in which only the coaches could send messages to the participants, and thirteen studies (40%) did not specify the directionality of the messages.

Only six studies (18%) reported use (or intended use in the case of protocol papers) of a fidelity check to ensure that prompts were being delivered as intended. These checks included asking participants whether they received the prompts (58,59,72), or by assessing communication reports to determine the number of prompts sent versus the number intended to be sent (52,65,79). Additional information pertaining to prompting content can be found in *Table 2*.

Prompt duration and timing

Of the 22 studies that included prompts as a part of a larger intervention, 15 delivered prompts during the structured intervention, five delivered prompts following the structured intervention, and two delivered prompts both during and following the intervention. Participants received prompts for an average of nine months (SD =6.55 months) ranging from 15 days of prompts to two years. Seventy percent of studies (n=23) did not specify the time of day in which prompts were sent to participants, and those that did provided only broad ranges. For example, Limaye and colleagues (84) stated that participants received prompts sometime between 10:00 am and 1:00 pm.

Prompting frequency

Six studies (18%) reported that prompts were sent at variable frequencies (52,54,60,74,75,85), most often decreasing prompting frequency over time. For example, Wong and colleagues (74) sent three prompts per week in the first three months, once per week in the following three months, and once per month in the final six months. Of those studies that had a static prompting frequency, participants received

Table 2 Information pertaining to mHealth prompt delivery

Reference	Were prompts part of larger DPP	Prompt type	Prompt duration	Prompt frequency	Prompt timing	Justification for message dose	Were any fidelity checks in place to ensure messages were delivered as intended?	Prompt sender	1 - or 2-way messages
Berkley-Patton <i>et al.</i> , [2020]	Larger	SMS	8 months	Not specified	Not specified	Not specified	Participants asked whether they received text messages over the 8-month intervention period	Outreach ministry leaders	Not specified
Polgreen <i>et al.</i> , [2018]	Stand-alone	SMS	180 days	1×/day	between 07:00 and 09:00 hours	Participant preference	Not specified	Automated	2-way
Gupta <i>et al.</i> , [2019]; Tewari <i>et al.</i> , [2020]; Shanthosh <i>et al.</i> , [2020]	Larger	SMS	Weeks 10–22 then weeks 32–48	2×/week	Not specified	Not specified	Trial administration data (number of successful messages sent each month) will be used to assess fidelity	Healthcare workers	Not specified
Cheung <i>et al.</i> , [2019]	Larger	SMS	26 weeks	3–4×/week	Not specified	Not specified	Not specified	Automated	2-way
Nanditha <i>et al.</i> , [2020]; Thomson <i>et al.</i> , [2018]	Stand-alone	SMS	2 years	2–3×/week	In India, messages sent 06:30–08:30 hours or after 18:00 hours. In the UK, messages were sent at 10:00 hours on alternate days	In India - participant preference	Not specified	Not specified	Not specified
Ram <i>et al.</i> , [2014]; Ramachandran <i>et al.</i> , [2013]; Nanditha <i>et al.</i> , [2018]	Stand-alone	SMS	2 years	Median of 3×/week	05:00–08:00 hours or 17:00–20:00 hours	Participant preference	Not specified	Automated	Not specified
Wong <i>et al.</i> , [2013]; Wong <i>et al.</i> , [2016]; Wong <i>et al.</i> , [2018]	Stand-alone	SMS	2 years	3×/week in months 0–3; 1×/week months 3–6; 1×/month in months 6–12	Not specified	Not specified	Not specified	Program staff	1-way

Table 2 (continued)

Table 2 (continued)

Reference	Were prompts part of larger DPP	Prompt type	Prompt duration	Prompt frequency	Prompt timing	Justification for message dose	Were any fidelity checks in place to ensure messages were delivered as intended?	Prompt sender	1 - or 2-way messages
Catley <i>et al.</i> , [2019]; Catley <i>et al.</i> , [2020]	Larger	SMS	Not specified	Protocol states 2x/day, preliminary findings state messages sent on a dynamic schedule	Morning and lunch time (protocol)	Not specified	Not specified	Not specified	Not specified
Block <i>et al.</i> , [2015a]; Block <i>et al.</i> , [2015b]	Larger	Push notifications	1 year	2x/week	Not specified	Prompts are reactive to the user reported goals and behaviour	Not specified	Automated, participants	1-way
Buis <i>et al.</i> , [2013a]; Buis <i>et al.</i> , [2013b]	Stand-alone	SMS	14 weeks	5–7x/week	Not specified	Not specified	Not specified	Automated	1-way
Ritchie <i>et al.</i> , [2020]; Fischer <i>et al.</i> , [2016]; Fischer <i>et al.</i> , [2019]	Larger	SMS	12 months	6x/week	Not specified	Participant preference	Participants asked if they received all messages. 5 participants reported not receiving 20 or more text messages throughout the 1-year intervention	Not specified	2-way
Morton <i>et al.</i> , [2015]; Yates <i>et al.</i> , [2015]	Larger	SMS	8 weeks in pilot then 12 months in protocol	Pilot: 1x/week and based on user behaviours. Protocol: first 2 months 1–3x/week; 2–6 months 1x/week; 7–12 months 1x/month	Not specified	Not specified	SMS delivery monitored by examining lists of messages sent and received. Pilot: 9 out of 11 participants received full SMS regimen as intended and 90% of participants reported no difficulties with the system and all messages were correctly formatted	Automated	2-way

Table 2 (continued)

Table 2 (continued)

Reference	Were prompts part of larger DPP	Prompt type	Prompt duration	Prompt frequency	Prompt timing	Justification for message dose	Were any fidelity checks in place to ensure messages were delivered as intended?	Prompt sender	1 - or 2-way messages
Everett <i>et al.</i> , [2018]	Larger	Push notifications	3 months	Not specified	Not specified	Tailored using advanced algorithms to optimally influence behaviour change	Not specified	Automated	1-way
Tkatch <i>et al.</i> , [2018]	Larger	SMS	Not specified	1×/day and 2×/week (Monday and Thursday)	Not specified	Not specified	There were 23 opportunities per person to send High-5's and an average of 11.26 were sent per person	Participants are sending High-5s to their peers	2-way
Limaye <i>et al.</i> , [2017]	Larger	SMS	1 year	3×/week	Between 10:00–13:00 hours	Participant preference	One-tenth of prompts requested a reply. Adherence calculated based on response to these requests	Not specified	2-way
Pfammatter <i>et al.</i> , [2016]	Stand-alone	SMS	6 months	1×/day for the first 6 days, then 2×/week	Not specified	Not specified	Not specified	Not specified	Not specified
Fukuoka <i>et al.</i> , [2015]	Larger	SMS/push notifications	5 months	1×/day	11:00 hours and 15:00 hours (only non-responders)	Not specified	Not specified	Automated	2-way
Abebe <i>et al.</i> , [2013]	Stand-alone	SMS	14 weeks	4–7×/week	Not specified	Not specified	Not specified	Clinic staff	2-way
González <i>et al.</i> , [2013]	Larger	SMS	15 days	Not specified	Not specified	Not specified	Not specified	Automated	1-way
Fukuoka <i>et al.</i> , [2011]	Stand-alone	Not specified	N/A	Participants want choice in message frequency	N/A	N/A	N/A	N/A	N/A

Table 2 (continued)

Table 2 (continued)

Reference	Were prompts part of larger DPP	Prompt type	Prompt duration	Prompt frequency	Prompt timing	Justification for message dose	Were any fidelity checks in place to ensure messages were delivered as intended?	Prompt sender	1- or 2-way messages
Alzeidan <i>et al.</i> , [2019]	Stand-alone	SMS	6 months	6x/week (2x/day for 3 days)	10:00–11:00 hours	Not specified	At every visit, participants will be asked the number of messages they received	Automated	1-way
Rosas <i>et al.</i> , [2018]	Larger	SMS	12 months	1x/week in months 1–3 and biweekly thereafter	Not specified	Not specified	Self-monitoring records and Smartphone app communication will be reviewed for quality control	Coach	2-way
Kim <i>et al.</i> , [2019]	Larger	SMS	6 months	1x/day	Not specified	Not specified	Not specified	Community health workers, research nurses	Not specified
Whelan <i>et al.</i> , [2019]	Stand-alone	Push notifications	6 weeks	Hourly then additional prompts tailored to participant behaviour	Motivational messages not specified. Hourly reminders to move 09:00–17:00 hours	Not specified	Prompt reports were audited to determine how many prompts were sent	Automated	1-way
MacPherson <i>et al.</i> , [2019]	Larger	Push notifications	1 year	1x/month, tailored based on participant behaviour	Not specified	Not specified	Not specified	Exercise counselors	2-way
O'Reilly <i>et al.</i> , [2019]	Larger	Push notifications	N/A	N/A	N/A	N/A	N/A	N/A	1-way
Staite <i>et al.</i> , [2020]	Larger	SMS	12 months	3–4x/day	Not specified	Not specified	Not specified	Automated	1-way
Ho <i>et al.</i> , [2020]	Stand-alone	SMS	12 months	First 6 months: 1x/month. Next 6 months: 1x/2 months	Not specified	Not specified	Not specified	Not specified	Not specified

Table 2 (continued)

Table 2 (continued)

Reference	Were prompts part of larger DPP	Prompt type	Prompt duration	Prompt frequency	Prompt timing	Justification for message dose	Were any fidelity checks in place to ensure messages were delivered as intended?	Prompt sender	1 - or 2-way messages
Shrivastava <i>et al.</i> , [2019]	Larger	Push notifications	Not specified	65x/week	Not specified	Not specified	User compliance with requests for dietary data input ranged from 59–87%, PA ranged from 52–93% and weight data ranged from 83–100%	Coach & physician	2-way
Xu <i>et al.</i> , [2020]	Larger	Push notifications	6 months	2x/week	Not specified	Not specified	Not specified	Automated	Not specified
Rollo <i>et al.</i> , [2020]	Larger	SMS	3 months	4x/week	Not specified	Not specified	Not specified	Not specified	Not specified
Sinclair <i>et al.</i> , [2020]	Larger	SMS	6 months	2x/week	Not specified	Not specified	Not specified	Not specified	Not specified
Harjuma <i>et al.</i> , [2020]	Larger	SMS	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified

DPP, diabetes prevention program; SMS, short message service; PA, physical activity.

an average of 11 prompts per week ($SD = 17.60$), ranging from two to 65 prompts weekly. The majority of studies ($n=24$, 73%) did not provide any justification for why they chose a specific prompting frequency. Those that did often cited that the timing or frequency of prompts was based on participant preferences (51,59,70,71,84). One study tailored prompt timing and frequency through use of algorithms to optimally influence behaviours (66). Everett and colleagues (66) used machine learning to translate information originating from participants mobile phone and digital body weight scale into insights about that persons physical activity habits and schedule. From that information, participants were sent just-in-time recommendations to guide them to achieve the daily physical activity and dietary recommendations. Advanced algorithms were then used to learn which message types resulted in better compliance for a specific user based on their specific context.

Outcomes

Acceptability outcomes

Twenty-one studies (64%) reported on outcomes relating to mHealth prompts. Acceptability was widely measured with 14 studies (42%) reporting patient satisfaction with prompts. Acceptability was primarily measured through participant surveys (55,64,67,69-71,75,76) and qualitative interviews or focus groups (52,53,65,83). Twelve of the studies reporting on acceptability found that prompts were well-received by participants; the remaining two studies found that prompts were not acceptable to participants. Specifically, participants in Whelan and colleagues study (53) felt that the hourly prompts to move were too burdensome, and they found the additional motivation prompts to be childish and not appropriate for an adult population at risk for developing T2D. Rollo and colleagues study (64) found that while 84% of participants agreed that the prompts provided useful information, only 22% felt that the prompts improved their self-efficacy, and only 8% felt it helped them achieve their goals. Further, participants noted that the primary focus on weight found in the prompts was not favourably received, and one participant suggested that motivational messages and informational messages on how different behaviours could reduce risk may be more appropriate (64).

Effectiveness outcomes

Nine studies (27%) assessed behavioural outcomes including weight loss (58,59), PA (51,53,71), exercise

(54,60), and diabetes incidence (70,71,74), and found mixed effects overall. In two studies, prompts were significantly associated with weight loss (58,59). In two studies that used Fitbit devices to push prompts to participants and assess activity levels, prompts were not associated with improved PA levels (51,53); however, they were associated with improved adherence to Fitbit wear (51). Studies which assessed both dietary and physical activity or exercise behaviours found that the prompts were associated with improved diet, but not physical activity or exercise behaviours (60,71). MacPherson and colleagues (54) found that prompts had an acute effect on exercise, and that a prompt resulted in increased exercise in the 3-day following a prompt. In terms of diabetes progression, one study demonstrated that diabetes incidence was significantly reduced by the prompting intervention 5-year post program (71). In contrast, Wong and colleagues (74) found that prompts were effective in reducing diabetes incidence during the 2-year program, but there were no significant differences between the prompting and control group three years post trial. Further, Nanditha and colleagues (70) found no significant reduction in diabetes incidence in the 2-year program.

Discussion

Principle findings

This scoping review summarizes the literature regarding use of mHealth prompts within DPPs. Our analysis highlights substantial heterogeneity coupled with a lack of reporting on the intervention duration, prompt delivery characteristics, prompt content, and fidelity. The majority of mHealth prompt literature to date has assessed feasibility or acceptability of mHealth prompts and has found that prompts are generally well-received by program participants.

Interestingly, 36 studies that were excluded at the full-text level identified that mHealth prompts were likely used in the intervention but provided insufficient information regarding the prompts to warrant inclusion. For example, Sweet and colleagues (86) provide only a single statement that participants are assigned to a lifestyle coach who can communicate with them through online messaging, with no indication of if the messages were pushed to their home screen, the number of messages that are sent by the coach, what the content is, how long the coach will continue to send messages, etc. This lack of reporting on key mHealth

intervention components used within DPPs hinders such programs from being translated into practice due to a lack of transparency about mHealth prompt use and how prompts may be influencing intervention effectiveness.

Beyond these 36 studies which were not included in this report due to their lack of information pertaining to prompts, the 33 studies that were included also consistently underreported on key delivery characteristics. Such underreporting may impede replication and translation of such interventions into practice. While it has been suggested that time of day and frequency in which prompts are sent can influence health behaviours (41), only seven studies (21%) reported prompt timing and 27 studies (82%) reported on prompt frequency, with 24 not providing any justification for why that frequency was chosen. Clearly, more thorough reporting is needed within mHealth prompt use in DPPs to allow for future meta-analyses to rigorously answer such questions.

Strengths and limitations

mHealth is a broad and heterogeneous field which is often assessed in its entirety and the impact of individual mHealth components not often teased apart. Assessing mHealth programs as an intervention package (e.g., assessing an app vs assessing those specific components within the app such as prompts and rewards) limits researchers abilities to identify which specific components (e.g., prompts) may be driving behaviour change (23,27,87). A strength of this review is that a single mHealth component, prompts, was singled out to provide a comprehensive overview of use-cases to date, and to provide concrete recommendations to further the field of mHealth within DPPs. This scoping review is the first to provide a summary of available evidence on mHealth prompts with DPPs. A key strength of this review is its inclusion of a range of study designs, and mHealth prompt delivery (either as a stand-alone intervention or to augment larger DPPs) allowing for a more robust overview of the scope of the literature. Additionally, by reporting on a variety of characteristics associated with prompts within DPPs (content, delivery mode, delivery schedule, theoretical underpinning, etc.) this review was able to identify gaps in the literature and avenues for future mHealth prompt researchers.

Limitations for the current review include confining the search to only English language publications. Further, some studies using mHealth prompts may have been missed in the search if the manuscript did not state that an mHealth

prompt derivative was used somewhere within the title or abstract, or if the full text did not explicitly state that the potential prompt would land on the participants home screen of their device. Additionally, there may be studies included in the current review in which participants were able to turn off push notifications at the app level, or blocked study related phone numbers sending text messages, suggesting that measures of mHealth prompt fidelity are needed (e.g., read/send reports). Lastly, due to the nature of scoping reviews coupled with the heterogeneity of included studies, we were unable to comment on the effectiveness of different prompt content and delivery characteristics.

Future directions

Our findings show an increasing focus on mHealth prompt use within DPPs with almost three quarters of the included studies published in the last five years. While there were mixed results of mHealth prompts on exercise behaviours and overall reduction in T2D incidence, it is unclear if prompting content or delivery may be driving these differences. Given the ubiquity of mobile phones, coupled with the overall acceptability of mHealth prompts within the context of diabetes prevention, future research should be conducted to determine how to optimally engage clients in the behaviour change process through mHealth prompts. To understand why prompts may be facilitating behaviour change in some studies, but not others, mHealth prompting content and delivery should be systematically developed, evaluated, and transparently reported.

mHealth prompt development

Use of behaviour change frameworks such as the Behaviour Change Wheel (BCW) (88) should guide the design of mHealth prompting interventions and provide structure when describing active intervention content. The BCW encourages intervention developers to use multiple data sources including previous literature, focus groups, surveys, and interviews with end users when developing an intervention. Regarding mHealth prompts, the BCW can be used to systematically develop theory-based prompt content in collaboration with end users, and to identify mechanisms of action by detailing BCTs within each message.

As the purpose of mHealth prompts is often to cue a target behaviour within an individual's own environment, contextual factors pertaining to mHealth prompt implementation should be accounted for during the

development phase. The BCW advises researchers to thoroughly identify and understand a target behaviour within a given context (88) and to take into account intervention Effectiveness, Affordability, Scalability, and Efficiency (EASE) (89). Intervention EASE is achieved by balancing the efficacy of an intervention with other contextual aspects (affordability, scalability, and efficiency) which may impact the ability of an intervention to be effectively implemented into a community setting (89).

One key factor which may influence mHealth prompting in DPPs is the reach and accessibility of prompts by target populations. The most frequently used mode of delivery for mHealth prompts in the current review were text messaging (73% of studies) and push notifications (21%). While both mHealth prompt types have broad reach, text messaging may be a more accessible and affordable mode of delivery among those most at risk for developing T2D.

Push notification reach

Despite similar levels of access to mobile broadband (18), mobile internet usage varies substantially between developed and least developed countries due to unaffordable broadband cost within developing countries (18). For example, 19% of individuals use internet in the 47 least developed countries compared to 87% of individuals using the internet in developed countries. The United Nations Broadband Commission for Sustainable Development set a target for what constitutes “affordable” broadband services; the least developed countries mobile broadband prices are six times higher than the broadband commissions affordability target compared to developed countries which cost less than half of the affordability target (18). This makes cost a potentially significant barrier to internet uptake. Discrepancies in uptake and subscriptions seen in internet use between developed and least developed countries may make mHealth prompts requiring internet enabled devices (e.g., push notifications) less accessible.

Text messaging reach

As cell phones do not require a mobile broadband connection to send and receive text messages, text messaging is one of the widest reaching and most accessible mHealth prompting interventions (90,91). The gaps in mobile broadband adoption and usage between the developed and least developed countries are much larger than the gap in cellular phone uptake which enables text messaging use (129 cellular telephone subscriptions in developed and 75 in least developed countries per 100

inhabitants) (18). There are more than five billion mobile phone users worldwide (91) with greater than 18 billion text messages sent every day (92). Further, text messaging has been noted as the most popular non-voice application on mobile phones among American adults (93), and a survey conducted in 2011 with 21 countries found that 75% of cell phone owners report regularly sending and receiving text messages (94).

Beyond cell phones accessibility, text messaging may be a more impactful delivery mode for mHealth prompting interventions due to its acceptability among patient groups who have limited access to healthcare resources (e.g., those in remote and rural locations) (95). In a review conducted by Wali *et al.* (95), 11 articles were assessed to summarize the literature on the use of mHealth interventions targeting cardiovascular disease management in Indigenous communities and low- and middle-income countries (LMIC). It was noted that the majority of Indigenous communities and LMIC populations reside in remote or rural areas with limited access to traditional Western health resources. Of the included studies, it was found that mHealth interventions resulted in positive behaviour change, including improved medication adherence, blood pressure monitoring and control, and self-care. Additionally, it was noted that within 83% of the studies in which text messaging was used, patients explicitly stated a preference for text messaging as a reminder system. In addition to rural and remote populations, text messaging usage is becoming more ubiquitous in older adults. While teens and younger adults reportedly send the greatest number of daily text messages (an average of 50 text messages per day in 2010) (93), cellular phone ownership and text messaging use has increased among older adults (96).

As risk of developing T2D is higher among lower socioeconomic groups and increases with age (97), text messaging has the capacity to reach and engage with the largest amount of potential participants compared to mHealth prompts which rely on internet enabled devices (i.e., push notifications send via smartphone applications). As such, we recommend that future mHealth prompting research target the comprehensive development and evaluation of text messaging prompts to allow for more scalable and inclusive mHealth DPP programming.

mHealth prompt evaluation

Once an intervention has been systematically developed and all active intervention components within the messages

have been identified, they should be rigorously tested to ensure they are effective within a given context. By understanding what specific BCTs are used within each prompt, researchers can not only test whether prompts in general are effective in enacting behaviour change, but also what specific techniques and mechanisms of action may be driving the effect. This can improve future uptake by ensuring that those prompts which are most impactful are translated into practice following rigorous testing within research facilities.

Beyond content, prompt delivery is also a key characteristic which has been underreported. Future research is needed to identify not only which BCTs are most influential, but also what prompt ‘dose’ (i.e., frequency, timing, intervention duration) may reduce T2D incidence the most by improving PA, and dietary behaviours. While previous research has postulated that prompt dose may influence behaviours (41), DPPs have relied primarily on user preferences and observational research to justify prompt timing and frequency. More rigorous experimental evidence regarding the impact of prompt timing and frequency on behaviour change is needed to advance the field of mHealth behaviour change. Factorial experiments, sequential multiple-assignment randomized trials (SMARTs), and micro-randomized trials are potential trial designs appropriate to examine the dose-response relationship between prompts and behaviour change.

mHealth prompt reporting

Findings from mHealth diabetes prevention programming are important to many groups from researchers to clinicians and patients, and public health diabetes prevention programmers. As such, research studies should be written in a way to increase their usability by including all relevant information pertaining to the study protocols and results so readers can judge the validity and relevance of the study, and if desired, use its findings to translate the project into other contexts (98); however, this review found that authors consistently underreport on the content, delivery, and fidelity of mHealth prompts within the context of DPPs. Transparent reporting is necessary to improve the translation of effective interventions into practice. If a complete description of an intervention is not available, clinicians, patients, and DPP developers are unable to reliably implement mHealth prompting interventions into different contexts, and other researchers are unable to replicate or build on a study’s findings (99).

To improve the quality of reporting within mHealth programming, future researchers should use standardized checklists to ensure that all relevant information is reported, and they should use a common language when describing intervention components. One tool which encourages and facilitates the reporting of key intervention details is the Template for Intervention Description and Replication (TIDieR) (99). The TIDieR provides a standardized checklist for researchers to follow to ensure that details regarding what was delivered, why those components were chosen, who delivered the intervention, mode of delivery and intervention dose, if the intervention was tailored or modified, and what fidelity checks were in place (99).

Further, using a common language across behavioural domains through standardized description of BCTs can allow for more comprehensive intervention development, more accurate replication of interventions, and improved translation of effective interventions into real-world settings (30). If BCTs are consistently and thoroughly reported (e.g., through the use of the BCTTv1), the opportunity for evidence synthesis within behaviour change science is increased thereby allowing for meta-analyses to comment on which BCTs or combination of BCTs may be most effective at enacting behaviour change. mHealth prompting interventions reporting their methods using standardized tools such as the TIDieR and BCTTv1 help future researchers know what intervention components make up an effective intervention and can allow for the replication or building on previous work. Understanding which BCTs make up an intervention, and how they were delivered is critical for effective mHealth scale-up and implementation (100).

These comprehensive and transparent reports are well situated within protocol papers and can be deposited to data repositories such as the Open Science Framework (<https://osf.io>). Beyond strictly reporting, possible interactions between these characteristics and BCTs should be assessed towards optimizing the effects of mHealth prompts on behaviour change.

Conclusions

mHealth prompts show mixed results on behavioural outcomes; however, they are consistently reported as well-received by those at risk for developing T2D. Results from this review mirror that of other mHealth prompting interventions delivered across a broad range of behaviours—few interventions detail the formative

development, and specifically the content development (101-105) which limits future replication or evaluation due to mHealth interventions which were developed within a 'black box' (103). Theoretical mechanisms underpinning prompts, development of prompt content, and prompting delivery characteristics are consistently underreported, leading to large heterogeneity in the field. Future research is needed to improve the impact mHealth prompts have on behaviour change and standardize prompt reporting. Understanding how to optimally intervene with mHealth prompts is necessary for the development and implementation of effective and scalable interventions to reach a wide range of individuals at risk for developing T2D.

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Footnote

Reporting Checklist: The authors have completed the PRISMA-ScR reporting checklist. Available at <https://mhealth.amegroups.com/article/view/10.21037/mhealth-21-22/rc>

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <https://mhealth.amegroups.com/article/view/10.21037/mhealth-21-22/coif>). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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MEDLINE search strategy**Table S1** Search terms

Prediabetes terms	mHealth prompt terms
Prediabetes	Texting
Diabetes risk	Short message service
Hyperglycemia	Brief messaging
Impaired glucose tolerance	Prompt
Prediabetic state*	Digital health
	mHealth
	Mobile phone
	eHealth
	Online
	Virtual
	Computer
	Telehealth
	Technology
	Telemedicine*
	Cell phone*
	Text messaging*
	Telecommunications*
	Smartphone*

*, MeSH Terms.

Table S2 Example search strategy (MEDLINE)

1. prediabetic state/
2. prediabet*.ab,ti or (diabet* adj3 risk.ab,ti) or (T2D adj3 risk.ab,ti) or (T2DM adj3 risk.ab,ti) or (TIIDM adj3 risk.ab,ti) or (diabet* adj3 prevent*.ab,ti) or (T2D adj3 prevent*.ab,ti) or (T2DM adj3 prevent*.ab,ti) or (TIIDM adj3 prevent*.ab,ti) or (impaired adj2 glucose.ab,ti) or hyperglyc*.ab,ti or glucose intoleran*.ab,ti or impaired fasting glucose.ab,ti or IGT.ab,ti or IFG.ab,ti or fasting hyperglyc*.ab,ti
3. 1 or 2
4. Telemedicine/ or Cell Phone/ or Text Messaging/ or Telecommunications/ or smartphone/
5. texting.ab,ti or "text messag*".ab,ti or "Short messag* service*".ab,ti
prompt.ab,ti or "digital health".ab,ti or mHealth.ab,ti or "cell* phone".ab,ti or "mobile phone".ab,ti or smartphone.ab,ti or "mobile health".ab,ti or eHealth.ab,ti or online.ab,ti or virtual.ab,ti or computer.ab,ti or digital.ab,ti or telehealth.ab,ti or technolog*.ab,ti or telephone.ab,ti or m-health.ab,ti or e-health.ab,ti or tele-health.ab,ti or "brief messag*".ab,ti
6. 4 or 5
7. 6 and 5