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**Mobile health as a primary mode of intervention for women at risk of, or diagnosed with, gestational diabetes mellitus**

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## 4 **Mobile health as a primary mode of intervention for women at risk** 5 **of, or diagnosed with, gestational diabetes mellitus: a scoping** 6 **review**

### 7 **Abstract**

8 **Introduction:** Prevention and management of GDM and its associated adverse outcomes are  
9 important to maternal and infant health. Women with GDM report high burden of disease  
10 management and barriers to lifestyle change post-delivery which mHealth interventions may help to  
11 overcome. Evidence suggests apps could help GDM prevention and management, however, less is  
12 known about broader applications of mHealth from preconception to interconception and whether  
13 relevant behavior change techniques (BCT) are incorporated.

14 **Objective:** To map the extent of knowledge related to the use of mHealth as primary mode of  
15 intervention for the prevention and management of GDM and its long-term implications among women  
16 at risk of or diagnosed with GDM. We also sought to understand if mHealth for women at risk of or  
17 diagnosed with GDM incorporated relevant behavior change theory and techniques.

18 **Inclusion criteria:** Studies, published in English, considered for inclusion focused on mHealth use as  
19 primary mode of intervention for the prevention and management of GDM and its long-term  
20 implications. Telehealth or telemedicine were excluded as these have been reviewed elsewhere.

21 **Methods:** Six databases were searched during March 2021; MEDLINE (Ovid), CINAHL (EBSCO),  
22 EMBASE (Ovid), Cochrane Database (Wiley), Scopus, and TRIP. No limits were applied to database  
23 exploration periods to ensure retrieval of all relevant studies. Also gray literature; Open Grey,  
24 ISRCTN Registry, ClinicalTrials.gov, EU Clinical Trials register, and ANZCTR. Two reviewers  
25 independently screened abstracts and assessed full texts against the inclusion criteria. Data were  
26 extracted using an adapted version of the JBI results extraction instrument. Data are presented in  
27 narrative form accompanied by tables and figures.

28 **Results:** This review identified 2166 sources, of which 96 full-texts were screened. Thirty eligible  
29 reports were included, covering 25 different mHealth interventions. Over half (14/25) were for self-  
30 managing blood glucose during pregnancy. Common features included tracking blood glucose levels,  
31 real-time feedback, communication with professionals and educational information. Few (6/25)  
32 mHealth were designed for postpartum use and none for interconception use. Five for postpartum use  
33 supported behavior change to reduce risk of type 2 diabetes and included additional features such as  
34 social support functions and integrated rewards. Early development and feasibility studies used mixed

35 methods to assess usability and acceptability. Later stage evaluations of effectiveness typically used  
36 randomized controlled trial designs to measure clinical outcomes such as glycemic control and  
37 reduced body weight. Three mHealth interventions were developed using behavior change theory.  
38 Most mHealth incorporated two BCTs shown to be optimal when combined and those delivering  
39 behavior change interventions included a wider range. Nevertheless, only half of the 26 techniques  
40 listed in a published behavior change taxonomy were tried.

41 **Conclusion:** mHealth for GDM focusses on apps to improve clinical outcomes. This focus could be  
42 broadened by incorporating existing resources that women value, such as social media, to address  
43 needs such as peer support. Although nearly all mHealth interventions incorporated BCTs, findings  
44 suggest future development should consider selecting techniques that target women's needs and  
45 barriers. Lack of mHealth intervention for prevention of GDM recurrence and T2DM suggests further  
46 development and evaluation is required.

47 **Keywords:** diabetes, gestational; mHealth; postpartum period; interconception; behavior change  
48 techniques

49 **Abstract word count: 499**

50

## 51 Introduction

52 Rapid development of technology has led to a quickly growing market for mobile health (mHealth),  
53 defined as "use of mobile and wireless technologies, such as mobile phones and personal digital  
54 assistants (PDAs), to support the achievement of health objectives".<sup>1</sup> Globally, smartphone ownership  
55 is estimated to be 78% in 2020.<sup>2</sup> An mHealth economics report found that apps for diabetes were one  
56 of the strongest markets within digital health innovation<sup>3</sup>, however, there are comparatively few apps  
57 targeting the prevention and management of Gestational Diabetes Mellitus (GDM).<sup>4</sup> GDM defined as  
58 "carbohydrate intolerance resulting in hyperglycemia of variable severity with onset or first recognition  
59 during pregnancy<sup>5</sup> presents as a significant pregnancy complication, and if not managed well, can  
60 result in adverse maternal, fetal and neonatal outcomes<sup>6,7</sup>. Longer-term implications for maternal  
61 health include reoccurrence of GDM in future pregnancies, and development of type 2 diabetes; two  
62 outcomes found to be independently associated with higher body mass index (BMI) ( $\geq 25\text{kg/m}^2$ )<sup>8,9</sup>.  
63 The prevalence of GDM is increasing worldwide<sup>10</sup> and in the UK, is expected to develop in 16 out of  
64 every 100 women.<sup>11</sup>

65 Effectively managing GDM following diagnosis is key to reducing the likelihood of adverse outcomes.  
66 Combinations of intervention such as dietary modification, exercise, blood glucose self-monitoring  
67 and/or pharmacological treatment are found to reduce most adverse perinatal outcomes compared to  
68 standard care.<sup>12</sup> mHealth interventions can offer highly scalable solutions to support disease  
69 management and prevention and have the advantage of being low cost, tailored to individual needs  
70 and have the ability to relay data to healthcare professionals. Commonly used mHealth technologies  
71 include apps, wearable sensors, social media, websites, and videoconferencing. In a recent survey of  
72 63 women in the UK, most of whom had GDM, 43/63 (73%) used smartphones to obtain health or  
73 pregnancy related information, and only 16/63 (25%) expressed concerns about using an app to  
74 monitor diabetes, suggesting an appetite among women with GDM for digitally supported services.<sup>13</sup>

75 A recent literature review by Nikolopoulos et al. aimed to identify and appraise apps implemented by  
76 healthcare providers for GDM care.<sup>14</sup> Three apps for supporting blood glucose monitoring were  
77 included. The review concluded that apps were a useful and practical way of reducing the burden of  
78 GDM. A scoping review, conducted in 2017, consolidated knowledge around the implementation,  
79 functionality, impact, and role of health literacy of mobile apps for GDM.<sup>15</sup> Seven different apps  
80 described across 12 articles were included and authors concluded that mobile apps have the potential  
81 to support prevention and management of GDM. However, consideration of health literacy may  
82 enhance usability and engagement and larger scale trials are required to evaluate app impact on  
83 health outcomes. While both these reviews show encouraging support for mobile apps for use in  
84 GDM care, particularly during pregnancy, we aimed to broaden the scope of this knowledge in a  
85 number of ways.

86 Firstly, we sought to explore the development, implementation and evaluation of all types of mHealth  
87 (rather than just apps) including, wearable sensors, websites and social media. Secondly, while the  
88 reviews by Nikolopoulos *et al.*<sup>14</sup> and Chen *et al.*<sup>15</sup> focus on app use prior to and during pregnancy, this  
89 review aimed to also include studies looking at the development, implementation or evaluation of  
90 mHealth to support women in the postpartum and interconception periods. Risk of progression to  
91 T2DM is estimated to be 10 fold higher in women with GDM compared to their normoglycaemic  
92 counterparts<sup>16</sup> and reoccurrence of GDM is thought to arise in 30% to 84% of subsequent  
93 pregnancies.<sup>6</sup> Consequently, the interconception and postpartum periods provide key windows of  
94 opportunity to reduce the likelihood of future GDM pregnancies, as well as onset of T2DM.<sup>17</sup>  
95 However, women with previous diagnosis of GDM encounter several barriers to engaging in face-to-  
96 face interventions, including time and financial constraints, childcare duties, fatigue and lack of  
97 motivation.<sup>18</sup> Thus, delivery of care via telephone or internet has been suggested as an optimal way of  
98 supporting this population during this time.<sup>19</sup>

99 In addition, following delivery, the transition from maternity to primary care is often complex and  
100 women report feelings of abandonment.<sup>20</sup> Studies report a lack of consensus on responsibility for  
101 follow-up care among professionals<sup>21</sup> and inconsistencies in information provided to women.<sup>22</sup> With  
102 this in mind, this review also sought to understand, how, when and where mHealth were implemented  
103 across preconception, pregnancy, postpartum and interconception periods.

104 Consequently, we developed and published a protocol for a scoping review aiming to provide an  
105 overview of the extent of the knowledge related to the use of mHealth as a primary mode of  
106 intervention for the prevention and management of GDM and its long-term implications among women  
107 at risk of or diagnosed with GDM.<sup>23</sup> The objectives of the proposed review were to identify gaps in  
108 knowledge by mapping the characteristics of all types of mHealth, their implementation contexts, and  
109 how they were evaluated. The proposed review also sought to understand if mHealth were developed  
110 using relevant behavior change theory. These objectives remain. However, during data extraction we  
111 discovered limited acknowledgement of behavior change theory among mHealth development, a  
112 finding congruent with the findings of Chen *et al.*<sup>15</sup>. Behavior change is an important concept  
113 throughout GDM prevention and management. Women must enact significant changes to their  
114 lifestyle in order to control and monitor their blood glucose levels (BGL), and to reduce risk of T2DM  
115 or recurrent GDM in future pregnancies. In order to further understand if mHealth of GDM included  
116 theory-based components we additionally extracted data on inclusion of behavior change techniques  
117 (BCTs). BCTs were identified using the 26-item taxonomy developed by Abraham and Michie.<sup>24</sup> This  
118 taxonomy was developed using variety of theoretical accounts of behavior change and each BCT can  
119 be mapped to various theoretical frameworks and therefore serves as a 'proxy' measure of theory-  
120 based development. An evaluation of diabetes apps found few included relevant BCTs.<sup>4</sup> One  
121 commercially available app for GDM was included in Hoppe *et al.*'s review, however, to-date no review  
122 has examined the use of BCTs across mHealth interventions developed specifically for GDM.

123 The objectives of this scoping review were, therefore, twofold: 1) to provide an overview of the extent  
124 of knowledge related to the use of mHealth as primary mode of intervention for the prevention and  
125 management of GDM and its long-term implications among women at risk of or diagnosed with GDM  
126 and 2) to understand if mHealth for GDM incorporated relevant behavior change theory and  
127 techniques.

128 A preliminary search of PROSPERO, MEDLINE, the Cochrane Database of Systematic Reviews, JBI  
129 Evidence Synthesis and the JBI Database of Systematic Reviews and Implementation Reports was  
130 conducted and no current or underway systematic or scoping reviews on the topic were identified. To  
131 the best of our knowledge, this scoping review is the first to address the objectives stated above. This  
132 review was conducted in accordance with an *a priori* protocol<sup>23</sup> but with the addition of extracting data  
133 regarding BCTs.

## 134 **Review question(s)**

- 135 1) What is known about using mHealth as a primary mode of intervention for the prevention and  
136 management of GDM and its long-term implications among women at risk of and diagnosed  
137 with GDM?
- 138 2) Do mHealth interventions for women at risk of and diagnosed with GDM, incorporate relevant  
139 behavior change theory and techniques, where appropriate?

## 140 **Inclusion criteria**

### 141 **Participants**

142 This review considered studies that included women who are at risk of GDM, currently have or have  
143 previously had a diagnosis of GDM. We acknowledge that women who have pre-existing diabetes  
144 (type1 or type 2) will continue to experience diabetes during pregnancy; however, because the focus  
145 of this review was on GDM, we excluded studies primarily focused on, or including, women with pre-  
146 existing Type 1 or Type 2 diabetes. Because we wanted to understand use of mHealth among women  
147 with a previous diagnosis of GDM (inter-conception and postpartum periods) no limit was placed on  
148 time since pregnancy occurred. No limits were placed on the inclusion of women with regards to their  
149 age, body weight, other comorbidities, mode of conception (e.g. physiological, assisted), or pregnancy  
150 status (e.g. single, multiple).

### 151 **Concept**

152 This review considered studies examining mHealth for GDM. mHealth has been defined as the use of  
153 mobile and wireless technologies to support the achievement of health objectives.<sup>1</sup> We included  
154 studies examining all types of mHealth technologies such as smartphone apps, wearable sensors,  
155 and social media use. Other types of mHealth were considered for inclusion but did not feature in the

156 studies selected for inclusion in this review. Studies focused on telehealth or telemedicine for GDM  
157 care, were excluded as these have been systematically reviewed elsewhere.<sup>25</sup> In cases where studies  
158 included mHealth as one component of a broader interventional approach, mHealth must have been  
159 the primary mode of intervention delivery to be considered for inclusion in this review.

## 160 **Context**

161 This review considered studies that were conducted in any geographical location and any setting  
162 (such as diabetes clinics, other hospital settings, primary care, community care and at home). With no  
163 commonly established implementation route, we aimed to include all settings within this review. With  
164 reference to our aim of understanding mHealth use for GDM before, during and after pregnancy we  
165 considered studies that examined mHealth during preconception, pregnancy, inter-conception and  
166 postpartum periods. We posed no limit to the timeframe of these periods as definitions can vary  
167 across different contexts. We posed no limit on study date as mHealth is a relatively new concept and  
168 we aimed to ensure the retrieval of all relevant studies.

## 169 **Types of sources**

170 This scoping review considered both experimental and quasi-experimental study designs including  
171 randomized controlled trials, non-randomized controlled trials, before and after studies and interrupted  
172 time-series studies. Study protocols were also considered for inclusion. Any systematic reviews that  
173 met the inclusion criteria were retrieved and their original source papers were searched for eligibility  
174 for inclusion.

175 In addition, analytical observational studies including prospective and retrospective cohort studies,  
176 case-control studies and analytical cross-sectional studies were considered for inclusion. We also  
177 considered descriptive observational study designs including case series, individual case reports and  
178 descriptive cross-sectional studies for inclusion. Qualitative studies were also considered that focus  
179 on qualitative data including, but not limited to, designs such as phenomenology, grounded theory,  
180 ethnography, qualitative description, action research and feminist research. Only studies published in  
181 English were included.

182 During the pilot search conducted during protocol development and prior to the full search strategy  
183 being developed, a google search of key words was undertaken and the first 5 pages reviewed. Only  
184 published literature was retrieved from this search and therefore this review focused on empirical  
185 studies only.

## 186 **Methods**

187 This scoping review was conducted in accordance with the Joanna Briggs Institute methodology for  
188 scoping reviews.<sup>26,27</sup> ~~This review was conducted in accordance with an a priori protocol<sup>28</sup> but with the~~  
189 ~~addition of extracting data regarding BCTs.~~

## 190 **Search strategy**

191 The search strategy aimed to locate published studies. An initial limited search of Scopus and  
192 MEDLINE was undertaken to identify articles on the topic. The text words contained in the titles and  
193 abstracts of relevant articles, and the index terms used to describe the articles were used to develop  
194 a full search strategy. The search strategy, including all identified keywords and index terms, was  
195 adapted for each included information source and a second search was undertaken. The full search  
196 strategies for each database are provided in Appendix I. The reference lists of all studies selected for  
197 inclusion were hand searched for additional studies.

## 198 **Information sources**

199 The databases searched were MEDLINE (via Ovid), CINAHL (via EBSCOhost, USA), EMBASE (via  
200 Ovid), Cochrane Database (via Wiley, USA) Scopus, and TRIP. Sources of unpublished studies and  
201 grey literature were searched using Open Grey, ISRCTN Registry, ClinicalTrials.gov, EU Clinical  
202 Trials register and ANZCTR.

## 203 **Study selection**

204 Following the search, all identified citations were collated and uploaded into Endnote X8, 2018  
205 (Clarivate Analytics, PA, USA) and duplicates removed. Titles and abstracts were screened by two  
206 independent reviewers (KE, KM) for assessment against the review inclusion criteria. Potentially  
207 relevant studies were retrieved in full and their citation details imported into the Joanna Briggs  
208 Institute System for the Unified Management, Assessment and Review of Information.<sup>28</sup> The full text  
209 of selected citations were assessed in detail against the inclusion criteria by two independent  
210 reviewers (KE, KM). Full text papers that did not meet the inclusion criteria were excluded and  
211 reasons for the exclusion are provided in Appendix II. Any disagreements that arose between the  
212 reviewers at each stage of the study selection process were resolved through discussion, or with a  
213 third reviewer (JS).

## 214 **Data extraction**

215 Data was extracted from papers included in the scoping review by two independent reviewers (KE,  
216 KM) using a data extraction tool developed by the reviewers and adapted from the JBI results  
217 extraction instrument (Appendix III). During the extraction we discovered limited acknowledgement of  
218 behavior change theory in full text articles. In order to gain a full understanding of the inclusion of



219 theory-based behavior change components the decision was taken to additionally extract data  
220 regarding BCTs. We therefore adapted the data extraction tool to include both behavior change  
221 theory and BCTs. BCTs identified from included full text articles were categorized based on the 26-  
222 item taxonomy developed by Abraham and Michie.<sup>24</sup> This taxonomy has been used previously to  
223 identify BCTs within diabetes apps.<sup>4</sup> The data extracted was tabulated and included: author, year of  
224 publication, origin, study design, mHealth objective, population, outcome measures, intervention type  
225 and purpose (e.g. app), setting, timing, technology features, behavior change theory, BCTs and key  
226 findings related to review objectives. Any disagreements that arose between reviewers were resolved  
227 through discussion, and with a third reviewer (JS). Authors of papers were contacted to request  
228 missing or additional data, where required.

## 229 **Data presentation**

230 The data extracted from full text articles are presented in tabular and diagrammatic form according to  
231 scoping review guidelines. An overview of our key review findings are presented in graphic form and  
232 are accompanied by a narrative summary that describes how the results related to the review  
233 questions and objectives.

## 234 **Results**

### 235 **Study inclusion**

236 Database searches retrieved 2166 records (Figure 1).<sup>29</sup> Grey literature searches identified 511  
237 records. After duplicates were removed, the remaining 1593 records were screened by title and  
238 abstract, and 1495 were excluded. The full text of 96 reports were assessed for eligibility, and another  
239 66 were excluded with reasons documented (Appendix II). Most reports were excluded due to  
240 ineligible intervention type (n=25) (e.g. mHealth was not the primary component of the intervention  
241 under investigation). Thirty reports were included.<sup>30-59</sup>

242

243 <insert Figure 1 here>

### 244 **Characteristics of included studies**

245 The 30 reports originated from 15 countries: Norway<sup>30,34,55</sup>, Iran<sup>35</sup>, Israel<sup>47</sup>, Spain<sup>53</sup>, Oman<sup>37</sup>,  
246 Germany<sup>41</sup>, New Zealand<sup>49</sup>, China<sup>36</sup>, Nepal<sup>52</sup>, USA<sup>31,32,54</sup>, Russia<sup>51</sup>, Australia<sup>48,50,57,58</sup>, South  
247 Korea<sup>39,40</sup>, Singapore<sup>42,59</sup>, and the UK<sup>33,38,43,44,46</sup>. Twenty five different mHealth interventions were  
248 described across the 30 reports. Around half (14/30) of the studies were early development of the  
249 technology and/or pilot studies, the other half (16/30) were later large studies such as RCTs (Table 1).

250 Of the 25 studies that reported results, 1303 participants were included (range 5-170). These 1303  
251 includes some 'double counting' (for example, participants reported in a qualitative sub study<sup>55</sup> and

252 different studies reporting results from the same service development project<sup>38,43,46</sup>). Six studies  
253 focused on postpartum women, the remaining 24 included, or aimed to include, women currently  
254 pregnant with GDM diagnosis (Table 1).

255 <insert Table 1 here>

## 256 **Review findings**

257 Appendix IV describes the relevant data from the included sources related to the review objectives  
258 including; mHealth purpose and features, study design, population, outcome measures,  
259 implementation and duration of use, behavior change theory and techniques and key study findings. A  
260 summary of this scoping review's main findings is provided in Figure 2.

261 <insert Figure 2 here>

## 262 **mHealth purpose**

263 All (25/25) mHealth required women to use an app, one of which enabled a mobile-based VR  
264 program with use alongside a VR headset<sup>40</sup> and one incorporated social media<sup>60</sup> (Table 1). Nearly all  
265 (24/25) mHealth were specifically developed for women experiencing GDM. One study described  
266 curating an ecosystem of five commercially available health and wellness apps to meet various self-  
267 management needs.<sup>49</sup>

268 For mHealth used during pregnancy there were three main purposes: 1) to support self-management  
269 for blood glucose control (BGC) 2) provide education and 3) to support behavior change for healthy  
270 lifestyle (Table 1). For mHealth used postpartum (6/25) there were two main purposes: 1) behavior  
271 change interventions for the prevention of T2DM and 2) providing education for lifestyle change.

## 272 **mHealth features and key findings**

273 **Self-management for BGC:** All GDM self-management apps included features that enabled BGL  
274 monitoring and management.<sup>30,32,36,37,39,45,47,49,50,51,53,56,57,58</sup> Many apps enabled interaction with  
275 healthcare professionals.<sup>36,45,47,49,50,53,56,57,58</sup> This interaction predominantly served to transmit BGL  
276 readings to HCPs who could provide feedback on BGL, diet and therapy adjustment where required.  
277 Some also enabled appointment booking<sup>47</sup>, a call back service<sup>45</sup> and ability to ask questions<sup>36,47</sup>. One  
278 app included a system to remind women to monitor their BGL twice per day.<sup>37</sup> One study described  
279 an in-app algorithm to predict BGLs and provide tailored feedback, based on data input by women  
280 and clinical guidelines.<sup>39</sup>

281 Some apps also enabled tracking of dietary intake and physical activity<sup>49,51,56,58</sup>, one included an  
282 embedded accelerometer.<sup>53</sup> Some apps also included educational materials regarding diet, physical  
283 activity and general information on GDM.<sup>30,32,36,37</sup> Studies exploring apps for self-management of BGC

284 suggest they were used, easy to navigate and were generally satisfactory for  
 285 women.<sup>38,39,43,45,46,47,49,51,58</sup>

286 **Education:** Two apps focused on delivery of education. One for use during pregnancy aimed to  
 287 increase risk perception of T2DM<sup>35</sup> and one for use postpartum provided health education to Spanish-  
 288 speaking Latina women<sup>31</sup> (Table 1). One app<sup>35</sup> included video, photo and text based educational  
 289 materials as well as reminders for tests and medications and an FAQ section regarding GDM and  
 290 T2DM. The Tu Puedes app included lessons about T2DM prevention that included culturally  
 291 applicable information.<sup>31</sup>

292 **Behavior change:** Nine mHealth interventions were developed to provide behavior change support  
 293 (table 1).<sup>33,40,41,42,44,48,52,54,59</sup> Of the four apps for use during pregnancy two<sup>33,59</sup> aimed to address  
 294 weight management, one to increase self-efficacy to adhere to physical activity and dietary  
 295 regimens<sup>52</sup> and one to motivate women to increase physical activity levels.<sup>44</sup> Five mHealth were  
 296 developed for the purpose of creating and sustaining health behavior change to prevent onset of  
 297 T2DM after pregnancy.<sup>40,41,42,48,54</sup>

298 Most apps included features to track physical activity, dietary intake and weight, track progress and  
 299 receive feedback.<sup>33,40,42,48,54,59</sup> One app also included motivational messages and interaction with  
 300 HCPs to provide feedback on progress.<sup>44</sup> mHealth for postpartum use included additional features of  
 301 social support via use of Facebook and provision of rewards.<sup>48,54</sup> Studies exploring apps for behavior  
 302 change suggest women's feedback at an early stage of design and development is important as some  
 303 features and functions were valued more than others.<sup>33,42,48,54</sup>

### 304 **mHealth implementation**

305 **When:** During pregnancy app use usually started at time of diagnosis (typically 24-28 weeks  
 306 gestation) and ceased on delivery (Appendix IV). Twelve of 19 mHealth required women to start using  
 307 them at specified gestation periods that ranged from 12-35 weeks  
 308 gestation.<sup>30,32,36,37,44,45,47,50,52,53,56,57,59</sup> One app implemented during pregnancy could be used up to  
 309 three months after delivery.<sup>30</sup> Timing of postpartum mHealth delivery varied from soon after  
 310 delivery<sup>40,42</sup>, three to eight months<sup>41</sup> post-delivery, and up to five years postpartum.<sup>54</sup>

311 **Where:** mHealth for use during pregnancy were typically introduced to women in hospital settings  
 312 (11/19), usually diabetes in pregnancy outpatient clinics (Table 1). One study describes recruiting  
 313 women online for app use at home.<sup>39</sup> Two mHealth for use postpartum were introduced to women at  
 314 their delivery location<sup>40,42</sup> and one from a community healthcare centre.<sup>54</sup>

315 **How:** Six studies detailing mHealth for use during pregnancy and two for use postpartum reported  
 316 that women received training on how to use the technology, including face to face  
 317 sessions<sup>40,44,45,47,54,56,58</sup> and a booklet.<sup>35</sup> Two studies relied on women's own capability to download

318 and start using apps.<sup>30,36</sup> Two apps included 'how-to' instructions.<sup>50,54</sup> Two studies report the app  
319 being set-up for women by researchers.<sup>35,52</sup>

## 320 **Behavior change theory and techniques**

321 Three studies described using behavior change theory to guide the development of mHealth  
322 interventions.<sup>30,52,54</sup> Borgen et al., based their app for self-management of BGC on Social Cognitive  
323 Theory.<sup>30</sup> Two apps designed to support behavior change, one during pregnancy<sup>52</sup> and one  
324 postpartum<sup>54</sup>, used the Health Belief Model to guide intervention development.

325 However, nearly all (22/25) mHealth interventions incorporated at least two BCTs. Of the 26 BCTs on  
326 the Michie and Abraham taxonomy<sup>24</sup>, 13 were identified as present across mHealth included in this  
327 review (Figure 2). The most common number of BCTs across all mHealth was 3 (Table 1).

328 mHealth developed specifically to deliver behavior change interventions typically included a broader  
329 range of BCTs (3-7) than those designed for education (1-4) or self-management of BGC (1-5).

330 All but one<sup>49</sup> mHealth intervention for supporting self-management of BGC, included both 'prompt  
331 self-monitoring behavior' and 'provision of feedback on performance'. These techniques mapped to  
332 functions that allowed women to monitor their blood glucose, physical activity, diet and weight and  
333 receive feedback on their performance, often in real-time.

334 mHealth for behavior change intervention during pregnancy included similar features to that included  
335 for self-management of BGC but additionally included identification of goals, information on health-  
336 behavior link and opportunity for social support. One also included motivational interviewing facilitated  
337 remotely within the app.<sup>44</sup>

338 mHealth to support behavior change postpartum included the widest range of BCTs per technology  
339 (5-7) (Table 1) and included self-monitoring features that tracked physical activity, dietary intake and  
340 monitored weight (Table 1). One technology<sup>40</sup> included techniques for stress management, one  
341 provided women with contingent rewards<sup>54</sup> and one provided opportunities for social support via  
342 social media.<sup>48</sup>

343 mHealth aimed at providing education for T2DM prevention included one<sup>31</sup> and four<sup>35</sup> techniques  
344 including 'prompt practice', 'information about behavior-health link' and 'information about  
345 consequence'. Although it could be argued that provision of education does not require behavior  
346 change, the evaluation of one educational app<sup>31</sup> included outcomes such as BMI, blood pressure and  
347 waist measurement suggesting the intended impact of the app was for women to make relevant  
348 lifestyle changes.

349 <insert Figure 3 here>

## 350 **Study Design**

351 **Development:** Of the two studies describing the mHealth development process, one used an iterative  
352 user-centered process with think-aloud interviews to assess usability<sup>34</sup>, the other drew on clinical  
353 guidelines and evaluated usability and acceptability using online surveys.<sup>39</sup>

354 **Pilot studies:** For mHealth used during pregnancy, pilot studies typically used surveys to capture  
355 data on usability, usage and patient satisfaction after women had used the app from diagnosis to  
356 delivery .<sup>33,34,38,39,43,46,51,57</sup> One study used an observational prospective study to understand  
357 compliance with BGL monitoring compared to a historical cohort who used standard monitoring  
358 methods.<sup>53</sup> A further pilot study used a single center RCT design to capture preliminary effectiveness  
359 of app use vs standard care via obstetric outcomes and OGTT results at 5-12 weeks postpartum.<sup>56</sup>

360 For postpartum mHealth, two pilot studies used quasi-experimental designs<sup>31,40</sup> to determine impact  
361 of mHealth use on various weight parameters and self-reported lifestyle behaviors. A further pilot  
362 study used qualitative methods to gather feedback from women on a prototype of a postpartum  
363 mHealth program.<sup>48</sup> Seely et al. describe the development, feasibility and preliminary effectiveness of  
364 their app using a series of studies involving qualitative feedback, usability testing and a single arm  
365 plot trial.<sup>54</sup>

366 **Efficacy evaluations:** The majority of studies evaluating clinical efficacy of mHealth for use during  
367 pregnancy typically used non-blinded randomized control trials, either single or multi-center (Table  
368 1).<sup>30,32,36,37,44,45,47,52,56,58,59</sup> Apps were used from diagnosis to delivery, and outcome measures focused  
369 on glycemic control (during pregnancy and at delivery), as well as various maternal, delivery and  
370 neonatal outcomes. Compliance with BG monitoring and satisfaction with the app were also  
371 measured. Postpartum (3 month) BGLs were measure as primary outcome in one trial however,  
372 significant loss to follow-up meant results could not be relied upon.<sup>30</sup>

373 For evaluations of postpartum mHealth, Lim et al. used a non-blinded single center RCT design to  
374 understand the impact of app use among 200 postpartum women on ability to restore booking weight  
375 at four months postpartum.<sup>42</sup> A parallel multi-center RCT with 64 postpartum women is planned to  
376 evaluate the Triangle app.<sup>41</sup> Primary outcome will be proportion of women reaching three or more of  
377 the five Diabetes Prevention Program lifestyle milestones. Secondary outcomes included physical  
378 activity, dietary intake, weight and BMI after six months of use.<sup>41</sup>

## 379 **Discussion**

380 This scoping review aimed to synthesize current knowledge on the use of mHealth as primary mode  
381 of intervention for the prevention and management of GDM and its long-term implications among  
382 women at risk of or diagnosed with GDM. We also aimed to understand if, where appropriate,  
383 mHealth for GDM incorporated relevant behavior change theory and techniques.

384 This review identified 30 sources of evidence that used mHealth as a primary mode of intervention to  
385 support women at risk of, and diagnosed with GDM. Despite broadening our search to include all  
386 types of mHealth (rather than just apps), all (25/25) required women to use an app. One study used  
387 an app to enable a mobile-based VR program with use of a headset, and only one included social  
388 media use. It is possible that other types of mHealth, such as websites, wearables and social media  
389 are not suited to address the clinical purpose of the mHealth described in this review. However, a  
390 recent study found women with experience of GDM frequently used and highly valued social media  
391 for meeting their informational and peer support needs.<sup>60</sup> These findings suggest future mHealth  
392 development should consider inclusion of existing online spaces women value in order to meet needs  
393 such as peer support, which have been found to impact women's ability to self-manage<sup>61</sup> and support  
394 behavior change.<sup>62</sup>

395 Building on the findings of Chen et al, this review included six studies evaluating the effectiveness of  
396 mHealth systems for self-management of BGC. In accordance with NICE guidelines<sup>63</sup> evaluations  
397 typically adopted RCT designs to measure the ability of mHealth to improve glycemic control in  
398 comparison to standard care. Women appeared satisfied with apps, however, the burden of managing  
399 GDM has been linked to feelings of depression and isolation among women <sup>64</sup> thus we suggest future  
400 evaluation of mHealth should consider wider reaching outcomes such as quality of life and wellbeing,  
401 in order to capture other important possible benefits for women. In addition, as recommended by  
402 Craig et al.<sup>65</sup> further qualitative exploration of women's experiences of app use could help to tease out  
403 barriers and facilitators that may enhance future adoption and efficacy.<sup>66</sup>

404 Only six of twenty five mHealth were designed for postpartum use and none were developed for the  
405 purpose of preventing GDM reoccurrence, despite high prevalence, particularly for those with high  
406 BMI.<sup>67</sup> mHealth for use after delivery typically focused on preventing progression to T2DM by creating  
407 behavior change for weight management, however, there is currently limited evidence examining their  
408 effectiveness. Weight increase during postpartum and interconception periods is an important  
409 modifiable factor known to increase the risk of progression to T2DM<sup>68</sup> and also recurrence of GDM in  
410 both normal and overweight/obese women.<sup>69</sup> Thus, finding effective, engaging and acceptable  
411 interventions is of key public health importance.

412 Because of a lack of published evidence, it was difficult to gain a thorough understanding of how,  
413 when and where postpartum mHealth was implemented. Both Lim and Kim demonstrated good  
414 engagement with intervention delivered soon after delivery. However, learning from evaluation of  
415 mHealth for use during pregnancy<sup>30</sup>, large loss to follow-up postpartum means that this relatively early  
416 timing needs to be balanced with women's barriers to engagement, including the pressures of new  
417 motherhood.<sup>18</sup> In addition, it is well documented that the transition from maternity to primary care,  
418 following delivery, can be fragmented.<sup>70</sup> Thus, early consideration of future implementation strategies  
419 will be essential for mHealth to function effectively within wider healthcare systems.

420 In line with findings from Chen *et al.*<sup>15</sup> only one app for self-management and two apps for behavior  
 421 change intervention were developed using behavior change theory. Although not all apps were  
 422 designed to deliver a behavior change intervention, self-management of BGC and education for  
 423 T2DM prevention require women to make changes to their lifestyle, suggesting a need for theory-  
 424 developed behavior change components. This is reflected in the finding that nearly all apps (24/25)  
 425 included at least two BCTs and those designed to support self-management of BGC nearly always  
 426 included two techniques seen as 'optimum' when combined.<sup>71</sup> mHealth for behavior change  
 427 intervention included a wider range of BCTs, nevertheless, of the twenty-six theory linked BCTs that  
 428 have been described and tested<sup>24</sup>, 13 were still not included within any mHealth reviewed. Clearly the  
 429 inclusion of all techniques is not realistic for all mHealth interventions, however, referring to the 26-  
 430 item taxonomy when developing mHealth for GDM could be advantageous for selecting specific BCTs  
 431 that might support women with particular needs. For example, evidence has shown women  
 432 experience a significant drop in motivation after delivery<sup>18</sup> and face-to-face motivational interviewing  
 433 has shown some promise for creating behavior change among postpartum women.<sup>72</sup> Despite this,  
 434 none of the mHealth interventions for postpartum behavior change included 'motivational interviewing'  
 435 techniques suggesting potential disparity between the BCTs included in postpartum mHealth  
 436 interventions and the barriers and needs women experience at this time.

## 437 **Limitations**

438 Our objective was to synthesize current knowledge and identify research gaps for future study,  
 439 however scoping methodology does not include quality assessment and consequently this review is  
 440 unable to identify the quality of included studies. In addition, due to lack of resource, only evidence  
 441 published in English were included and thus our findings may have omitted evidence in other  
 442 languages.

443 A further limitation was that BCTs were extracted using descriptions of mHealth provided in studies,  
 444 rather than by direct examination and thus some features/techniques may have been missed. Direct  
 445 examination of mHealth was beyond the scope of this review but is something that could be  
 446 undertaken in future work.

447 The lack of studies focused on postpartum mHealth interventions may be reflected in our decision to  
 448 include mHealth as the primary component of the intervention. For example, several studies were  
 449 excluded where mHealth was used for postpartum intervention, but was not the main component  
 450 (Appendix II). Postpartum interventions are typically more complex and may therefore require a  
 451 broader approach. Nevertheless, of the 98 studies taken to full text screening, only 23 focused on  
 452 postpartum usage and one for interconception care (Appendix II).



## 453 **Conclusions**

454 This scoping review has identified the majority of mHealth interventions for GDM are apps that aim to  
455 improve clinical outcomes during pregnancy. Further consideration of broader outcomes related to  
456 women's wellbeing and qualitative experiences is required to further inform improvement of these  
457 systems. In addition, consideration should be given to the inclusion of other existing resources such  
458 as social media that could help address needs such as peer support that impact on women's ability to  
459 self-manage.

460 It was previously unknown if BCTs were included within mHealth for GDM where appropriate. Our  
461 findings suggest most mHealth included BCTs. However, coming from a pragmatist position we  
462 suggest that in order for mHealth interventions to have maximum impact, intervention developers  
463 should consider referring to the 26-item taxonomy in order to select techniques that map to women's  
464 reported behavior change barriers. Overall, a lack of published studies examining mHealth for  
465 postpartum and interconception use indicates that further high-quality primary research is needed to  
466 better understand and identify effective ways of using mHealth to reduce risks associated with GDM  
467 recurrence and progression to T2DM. We suggest that once evidence is available regarding the  
468 impact of postpartum and interconception mHealth interventions, a systematic review is warranted to  
469 understand how specific features, BCTs and aspects of implementation may impact their efficacy.

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## 472 **Conflicts of interest**

473 All authors declare no conflict of interest.

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678 based cohort study. *BJOG An Int J Obstet Gynaecol* 2020;127(13):1608–16.
- 679 70. McCloskey L, Sherman ML, St. John M, Siegel H, Whyte J, Iverson R, *et al.* Navigating a  
680 'Perfect Storm' on the Path to Prevention of Type 2 Diabetes Mellitus After Gestational  
681 Diabetes: Lessons from Patient and Provider Narratives. *Matern Child Health J* 2019;0(0):0.
- 682 71. Michie S, Abraham C, Whittington C, McAteer J, Gupta S. Effective Techniques in Healthy  
683 Eating and Physical Activity Interventions: A Meta-Regression. *Heal Psychol* 2009;28(6):690.

- 684 72. Reinhardt JA, van der Ploeg HP, Grzegorzulka R, Timperley JG. Implementing lifestyle change  
685 through phone-based motivational interviewing in rural-based women with previous gestational  
686 diabetes mellitus. *Health Promot J Austr* 2012;23: 5–9.



687 **Appendix I: Search strategy**

688 MEDLINE (Ovid)

689 Ovid MEDLINE(R) and In-Process & Other Non-Indexed Citations 1946 to March 22, 2021

690 Search conducted on 22<sup>nd</sup> March 2021

#	Searches	Results
1	Diabetes, Gestational/	10831
2	"gestational diabet* ".ab,kf,ti.	14857
3	GDM.ab,kf,ti.	7316
4	(pregnancy adj3 diabetes).ab,kf,ti.	5558
5	((pregnan* or gestation* or maternal) adj3 glucose intolerance).ab,kf,ti.	356
6	((pregnan* or gestation* or maternal) adj3 impaired glucose tolerance).ab,kf,ti.	316
7	(hyperglyc#emia adj3 pregnan*).ab,kf,ti.	160
8	(hyperglyc#emia adj3 gestation*).ab,kf,ti.	53
9	(maternal adj2 hyperglyc#emia).ab,kf,ti.	126
10	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9	20535
11	Telemedicine/	23311
12	telemedicine.ab,kf,ti.	12644
13	(ehealth or "e health").ab,kf,ti.	6479
14	(mhealth or "m health").ab,kf,ti.	5199
15	("mobile health" or "mobile technolog*").ab,kf,ti.	6171
16	("digital health" or "digital technolog*").ab,kf,ti.	3630
17	Smartphone/	4496
18	(smartphone* or "smart phone*").ab,kf,ti.	12266
19	Cell Phone/	8547
20	("cell* phone*" or "mobile phone*").ab,kf,ti.	11632
21	Mobile Applications/	6023
22	("mobile app" or "mobile apps" or "mobile application*").ab,kf,ti.	4702
23	Text Messaging/	2918
24	"text messag* ".ab,kf,ti.	4132
25	Social Media/	8027

26	"social media".ab,kf,ti.	11373
27	(website* or online or internet).ab,kf,ti.	172358
28	(whatsapp or facebook or twitter or instagram).ab,kf,ti.	6342
29	Internet/	73031
30	Computers, Handheld/	3611
31	("personal digital assistant" or PDA).ab,kf,ti.	11969
32	(tablet* adj3 (comput* or device*)).ab,kf,ti.	1648
33	bluetooth.ab,kf,ti.	1134
34	"monitoring device* ".ab,kf,ti.	3651
35	"wireless device* ".ab,kf,ti.	402
36	(smartwatch* or "smart watch*").ab,kf,ti.	421
37	("fitness tracker*" or fitbit*).ab,kf,ti.	727
38	Fitness Trackers/	560
39	11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38	289282
40	10 and 39	299

691

692 EMBASE (Ovid) <1974 to 2021 March 22>

693

694 Search conducted on 22<sup>nd</sup> March 2021

695

#	Searches	Results
1	pregnancy diabetes mellitus/	30420
2	"gestational diabet* ".ab,kw,ti.	23815
3	GDM.ab,kw,ti.	11938
4	(pregnancy adj3 diabetes).ab,kw,ti.	6887
5	((pregnan* or gestation* or maternal) adj3 glucose intolerance).ab,kw,ti.	567
6	((pregnan* or gestation* or maternal) adj3 impaired glucose tolerance).ab,kw,ti.	423
7	(hyperglyc#emia adj3 pregnan*).ab,kw,ti.	257
8	(hyperglyc#emia adj3 gestation*).ab,kw,ti.	70
9	(maternal adj2 hyperglyc#emia).ab,kw,ti.	174
10	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9	36728

11	telemedicine/	22918
12	telemedicine.ab,kw,ti.	16568
13	(ehealth or "e health").ab,kw,ti.	7294
14	(mhealth or "m health").ab,kw,ti.	4530
15	("mobile health" or "mobile technolog*").ab,kw,ti.	6289
16	("digital health" or "digital technolog*").ab,kw,ti.	3828
17	smartphone/	11579
18	(smartphone* or "smart phone*").ab,kw,ti.	16237
19	mobile phone/	16365
20	("cell* phone*" or "mobile phone*").ab,kw,ti.	14061
21	mobile application/	10300
22	("mobile app" or "mobile apps" or "mobile application*").ab,kw,ti.	5445
23	text messaging/	4746
24	"text messag* ".ab,kw,ti.	5228
25	social media/	18892
26	"social media".ab,kw,ti.	15015
27	(website* or online or internet).ab,kw,ti.	244683
28	(whatsapp or facebook or twitter or instagram).ab,kw,ti.	8807
29	Internet/	107422
30	personal digital assistant/	1433
31	("personal digital assistant" or PDA).ab,kw,ti.	16548
32	(tablet* adj3 (comput* or device*)).ab,kw,ti.	2533
33	bluetooth.ab,kw,ti.	1688
34	"monitoring device* ".ab,kw,ti.	5135
35	"wireless device* ".ab,kw,ti.	530
36	(smartwatch* or "smart watch*").ab,kw,ti.	494
37	("fitness tracker*" or fitbit*).ab,kw,ti.	1006
38	activity tracker/	777
39	11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37	395248
40	10 and 39	647

696

697 Cochrane Library (<https://www.cochranelibrary.com/>)

698 Search conducted on 22<sup>nd</sup> March 2021

ID	Search	Hits
#1	MeSH descriptor: [Diabetes, Gestational] explode all trees	904
#2	MeSH descriptor: [Telemedicine] explode all trees	2343
#3	MeSH descriptor: [Cell Phone] explode all trees	1238
#4	MeSH descriptor: [Text Messaging] explode all trees	765
#5	MeSH descriptor: [Social Media] explode all trees	129
#6	MeSH descriptor: [Internet] explode all trees	3776
#7	MeSH descriptor: [Computers, Handheld] explode all trees	571
#8	MeSH descriptor: [Fitness Trackers] explode all trees	77
#9	MeSH descriptor: [Smartphone] explode all trees	314
#10	("gestational diabet*"):ti,ab,kw OR (GDM):ti,ab,kw OR ((pregnancy NEAR/3 diabetes)):ti,ab,kw OR (((pregnan* or gestation* or maternal) NEAR/3 glucose intolerance)):ti,ab,kw OR (((pregnan* or gestation* or maternal) NEAR/3 impaired glucose tolerance)):ti,ab,kw in Cochrane Reviews, Cochrane Protocols, Trials, Clinical Answers, Editorials, Special collections (Word variations have been searched)	2945
#11	((hyperglyc#emia adj3 pregnan*)):ti,ab,kw OR ((hyperglyc#emia NEAR/3 gestation*)):ti,ab,kw OR ((maternal NEAR/2 hyperglyc#emia)):ti,ab,kw in Cochrane Reviews, Cochrane Protocols, Trials, Clinical Answers, Editorials, Special collections (Word variations have been searched)	0
#12	#1 OR #10 OR #11 in Cochrane Reviews, Cochrane Protocols, Trials, Clinical Answers, Editorials, Special collections	3015
#13	(telemedicine):ti,ab,kw OR ((ehealth or "e health"):ti,ab,kw OR ((mhealth or "m health"):ti,ab,kw OR (("mobile health" or "mobile technolog*"):ti,ab,kw OR (("digital health" or "digital technolog*"):ti,ab,kw in Cochrane Reviews, Cochrane Protocols, Trials, Clinical Answers, Editorials, Special collections (Word variations have been searched)	6372
#14	((smartphone* or "smart phone*"):ti,ab,kw OR (("cell* phone*" or "mobile phone*"):ti,ab,kw OR (("mobile app" or "mobile apps" or "mobile application*"):ti,ab,kw OR ("text messag*"):ti,ab,kw OR ("social media"):ti,ab,kw in Cochrane Reviews, Cochrane Protocols, Trials, Clinical Answers, Editorials, Special collections (Word variations have been searched)	10170
#15	((website* or online or internet)):ti,ab,kw OR ((whatsapp or facebook or twitter or instagram)):ti,ab,kw OR (("personal digital assistant" or PDA)):ti,ab,kw OR ((tablet* adj3 (comput* or device*)):ti,ab,kw OR (bluetooth):ti,ab,kw in Cochrane Reviews, Cochrane Protocols, Trials, Clinical Answers, Editorials, Special collections (Word variations have been searched)	23186
#16	("monitoring device*"):ti,ab,kw OR ("wireless device*"):ti,ab,kw OR ((smartwatch* or "smart	1560

	watch*"):ti,ab,kw OR (("fitness tracker*" or fitbit*"):ti,ab,kw in Cochrane Reviews, Cochrane Protocols, Trials, Clinical Answers, Editorials, Special collections (Word variations have been searched)	
#17	#13 OR #14 OR #15 OR #16 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 in Cochrane Reviews, Cochrane Protocols, Trials, Clinical Answers, Editorials, Special collections	35890
#18	#12 AND #17 in Cochrane Reviews, Cochrane Protocols, Trials, Clinical Answers, Editorials, Special collections	225

699

700 CINHAL (EBSCO) with Full Text – Boolean/Phrase

701 Search conducted on 22<sup>nd</sup> March 2021

702 MH= exact subject heading

703 TI = Title

704 AB = Abstract

705 N2, N3 = Finds the words if they are within two or three words of each other regardless of order

ID	Search	Results
S1	(MH "Diabetes Mellitus, Gestational")	6,870
S2	TI "gestational diabet*" OR AB "gestational diabet**"	7,372
S3	TI gdm OR AB gdm	2,992
S4	TI (pregnancy N3 diabetes) OR AB (pregnancy N3 diabetes)	2,441
S5	TI ( ((pregnan* or gestation* or 24maternal) N3 glucose intolerance) ) OR AB ( ((pregnan* or gestation* or maternal) N3 glucose intolerance) )	128
S6	TI ( ((pregnan* or gestation* or maternal) N3 impaired glucose tolerance) ) OR AB ( ((pregnan* or gestation* or maternal) N3 impaired glucose tolerance) )	126
S7	TI (hyperglyc#emia N3 pregnan*) OR AB (hyperglyc#emia N3 pregnan*)	269
S8	TI (hyperglyc#emia N3 gestation*) OR AB (hyperglyc#emia N3 gestation*)	71
S9	TI (maternal N2 hyperglyc#emia) OR AB (maternal N2 hyperglyc#emia)	168
S10	(S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9)	10,391
S11	(MH "Telemedicine") OR (MH "Telehealth")	19,804
S12	TI telemedicine OR AB telemedicine	5,116
S13	TI ( (ehealth or "e health" ) ) OR AB ( (ehealth or "e health" ) )	3,466
S14	TI ( (mhealth or "m health" ) ) OR AB ( (mhealth or "m health" ) )	1,817
S15	TI ( ("mobile health" or "mobile technolog*") ) OR AB	2,991

	( ("mobile health" or "mobile technolog**") )	
S16	TI ( ("digital health" or "digital technolog**") ) OR AB ( ("digital health" or "digital technolog**") )	2,103
S17	(MH "Smartphone") OR (MH "Mobile Applications") OR (MH "Text Messaging") OR (MH "Computers, Hand-Held") OR (MH "Cellular Phone")	17,513
S18	TI ( (smartphone* or "smart phone**") ) OR AB ( (smartphone* or "smart phone**") )	6,343
S19	TI ( ("cell* phone**" or "mobile phone**") ) OR AB ( ("cell* phone**" or "mobile phone**") )	4,970
S20	TI ( ("mobile app" or "mobile apps" or "mobile application**") ) OR AB ( ("mobile app" or "mobile apps" or "mobile application**") )	2,753
S21	TI "text messag**" OR AB "text messag**"	2,738
S22	(MH "Social Media")	14,813
S23	TI "social media" OR AB "social media"	10,578
S24	(MH "Internet")	49,301
S25	TI ( (website* or online or internet) ) OR AB ( (website* or online or internet) )	104,439
S26	TI ( (whatsapp or facebook or twitter or instagram) ) OR AB ( (whatsapp or facebook or twitter or instagram) )	7,490
S27	TI ( ("personal digital assistant" or PDA) ) OR AB ( ("personal digital assistant" or PDA) )	2,115
S28	TI ( (tablet* N3 (comput* or device*)) ) OR AB ( (tablet* N3 (comput* or device*)) )	1,049
S29	TI bluetooth OR AB bluetooth	336
S30	TI "monitoring device**" OR AB "monitoring device**"	1,134
S31	TI "wireless device**" OR AB "wireless device**"	131
S32	TI ( (smartwatch* or "smart watch**") ) OR AB ( (smartwatch* or "smart watch**") )	205
S33	(MH "Fitness Trackers")	191
S34	TI ( ("fitness tracker**" or fitbit*) ) OR AB ( ("fitness tracker**" or fitbit*) )	450
S35	S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30 OR S31 OR S32 OR S33 OR S34	190,978
S36	(S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30 OR S31 OR S32 OR S33 OR S34) AND (S10 AND S35)	222

706  
707

708 Scopus (ELSEVIER)

709 Search conducted on 22<sup>nd</sup> March 2021

710 ( ( TITLE-ABS-KEY ( "Gestational diabetes" ) OR TITLE-ABS-KEY ( "gestational diabet\*\*" ) OR  
711 TITLE-ABS-KEY ( gdm ) OR TITLE-ABS-KEY ( pregnancy W/3 diabetes ) OR TITLE-ABS-KEY ( ( ( (pregnan\* OR gestation\* OR maternal ) W/3 glucose AND intolerance ) ) OR TITLE-ABS-KEY ( ( (pregnan\* OR gestation\* OR maternal ) W/3 impaired AND glucose AND tolerance ) ) OR  
712 ( (pregnan\* OR gestation\* OR maternal ) W/3 glucose AND intolerance ) ) OR TITLE-ABS-KEY ( ( (pregnan\* OR gestation\* OR maternal ) W/3 impaired AND glucose AND tolerance ) ) OR  
713 TITLE-ABS-KEY ( ( hyperglyc#emia W/3 pregnan\* ) ) OR TITLE-ABS-KEY ( ( hyperglyc#emia W/3

715 gestation\* ) ) OR TITLE-ABS-KEY ( ( maternal AND adj2 AND hyperglyc#emia ) ) ) AND ( (   
 716 TITLE-ABS-KEY ( telemedicine ) OR TITLE-ABS-KEY ( ( ehealth OR "e health" ) ) OR TITLE-   
 717 ABS-KEY ( ( mhealth OR "m health" ) ) OR TITLE-ABS-KEY ( ( "mobile health" OR "mobile   
 718 technolog\*" ) ) OR TITLE-ABS-KEY ( ( "digital health" OR "digital technolog\*" ) ) OR TITLE-ABS-   
 719 KEY ( ( smartphone\* OR "smart phone\*" ) ) OR TITLE-ABS-KEY ( ( "cell\* phone\*" OR "mobile   
 720 phone\*" ) ) OR TITLE-ABS-KEY ( ( "mobile app" OR "mobile apps" OR "mobile application\*" ) )   
 721 OR TITLE-ABS-KEY ( "text messag\*" ) OR TITLE-ABS-KEY ( "social media" ) OR TITLE-ABS-   
 722 KEY ( ( website\* OR online OR internet ) ) OR TITLE-ABS-KEY ( ( whatsapp OR facebook OR   
 723 twitter OR instagram ) ) OR TITLE-ABS-KEY ( internet ) OR TITLE-ABS-KEY ( "handheld   
 724 computer" ) OR TITLE-ABS-KEY ( ( "personal digital assistant" OR pda ) ) OR TITLE-ABS-KEY ( (   
 725 tablet\* W/3 ( comput\* OR device\* ) ) ) OR TITLE-ABS-KEY ( bluetooth ) OR TITLE-ABS-KEY (   
 726 "monitoring device\*" ) OR TITLE-ABS-KEY ( "wireless device\*" ) OR TITLE-ABS-KEY ( (   
 727 smartwatch\* OR "smart watch\*" ) ) OR TITLE-ABS-KEY ( ( "fitness tracker\*" OR fitbit\* ) ) ) ) )

728 587 records retrieved

729 TRIP Turning Research into Practice (<https://www.tripdatabase.com/>)

730 Search conducted on 22<sup>nd</sup> March 2021

#	Search	Results
1.	("Gestational diabetes") OR ("gestational diabet*") OR (gdm) OR (pregnancy diabetes) OR (((pregnan* OR gestation* OR maternal) glucose AND intolerance)) (((pregnan* OR gestation* OR maternal ) impaired AND glucose AND tolerance)) OR ((hyperglyc#emia pregnan* )) ((hyperglyc#emia gestation*)) ((maternal AND hyperglyc#emia)))	4,370
2.	((telemedicine) OR ((ehealth OR "e health")) ((mhealth OR "m health")) OR (("mobile health" OR "mobile technolog*")) (("digital health" OR "digital technolog*")) OR ((smartphone* OR "smart phone*")) ("cell* phone*" OR "mobile phone*")) OR (("mobile app" OR "mobile apps" OR "mobile application*")) OR ("text messag*" OR "social media") OR ((website* OR online OR internet)) OR ((whatsapp OR facebook OR twitter OR instagram)) OR (internet) OR ("handheld computer") OR (("personal digital assistant" OR pda)) OR ((tablet* (comput* OR device*))) OR (bluetooth) OR ("monitoring device*") OR ("wireless device*") OR ( (smartwatch* OR "smart watch*") ) OR ( ("fitness tracker*" OR fitbit* ) ) )	172
3.	#1 AND #2	186

731

732 Open Grey

733 Search conducted on 22<sup>nd</sup> March 2021

#	Search	Results
1.	Gestational diabetes	42

734

735 ISRCTN Registry (<https://www.isrctn.com/>)

736 Search conducted on 22<sup>nd</sup> March 2021

#	Search	Results
1.	Gestational diabetes	194

737

738 ClinicalTrials.gov (<https://clinicaltrials.gov/>)

739 Search conducted on 22<sup>nd</sup> March 2021

#	Search	Results
1.	Gestational diabetes AND mHealth	11
2.	Gestational diabetes AND eHealth	5
3.	Gestational diabetes AND smartphone	13
4.	Gestational diabetes AND technology	26

740

741 EU Clinical Trails Register (<https://www.clinicaltrialsregister.eu/>)

742 Search conducted on 22<sup>nd</sup> March 2021

#	Search	Results
1.	Gestational diabetes	61

743

744 Australia and New Zealand Clinical Trials Registry (<https://www.anzctr.org.au/>)

745 Search conducted on 22<sup>nd</sup> March 2021

#	Search	Results
1.	Gestational diabetes	164

746

747



748 **Appendix II: Studies ineligible following full text review**

749

750 Adepoju IOO, Douwes R, Abugnaba-Abanga R, Van Der Heiden M, Apentibadek N, Zweekhorst M, et  
751 al. MHealth for improving quality of antenatal care in northern Ghana: The Bliss4Midwives project.  
752 Trop Med Int Heal. 2017;22:81.

753 **Reason for exclusion:** Ineligible intervention: mHealth not the main intervention component

754 Albert L, Capel I, Garcia-Saez G, Martin-Redondo P, Hernando ME, Rigla M. Managing gestational  
755 diabetes mellitus using a smartphone application with artificial intelligence (SineDie) during the  
756 COVID-19 pandemic: Much more than just telemedicine. Diabetes Res Clin Pract. 2020;169:108396.

757 **Reason for exclusion:** Ineligible source type

758 ANZCTR. Continuous Glucose Monitoring (CGM) for women with Gestational Diabetes Mellitus  
759 (GDM) study: pilot. [Internet]. 2018. [cited 2021 Mar 22]. Available from:  
760 <https://www.anzctr.org.au/Trial/Registration/TrialReview.aspx?id=374153>.

761 **Reason for exclusion:** Ineligible intervention: Not mHealth

762 Aranda MIF. Technological advances in the follow-up of diabetic pregnant women. Matronas Prof.  
763 2017;18(4):e64–72.

764 **Reason for exclusion:** Article not available in English

765 Artola G, Torres J, Larburu N, Álvarez R, Muro N. Development and Usability Assessment of a  
766 Semantically Validated Guideline-Based Patient-Oriented Gestational Diabetes Mobile App. In Fred  
767 A, Salgado A, Aveiro D, Dietz J, Bernardino J, Filipe J. Eds. Knowledge Discovery, Knowledge  
768 Engineering and Knowledge Management. Spain: Springer Science and Business Media Deutschland  
769 GmbH. 2020; p.237–59.

770 **Reason for exclusion:** Unable to access full text

- 771 Bartholomew ML, Church K, Graham G, Burlingame J, Zalud I, Sauvage L, et al. Managing diabetes  
772 in pregnancy using cell phone/internet technology. *Am J Obstet Gynecol.* 2011;204(1):S113-S114.
- 773 **Reason for exclusion:** Ineligible intervention: Telemedicine
- 774 Bogaerts A, Ameye L, Bijlholt M, Amuli K, Heynickx D, Devlieger R. INTER-ACT: Prevention of  
775 pregnancy complications through an e-health driven interpregnancy lifestyle intervention - Study  
776 protocol of a multicentre randomised controlled trial. *BMC Pregnancy Childbirth.* 2017;17(1):1–9.
- 777 **Reason for exclusion:** Ineligible intervention: mHealth not the main intervention component
- 778 Borgen I, Garnweidner-Holme LM, Jacobsen AF, Bjerkan K, Fayyad S, Joranger P, et al. Smartphone  
779 application for women with gestational diabetes mellitus: A study protocol for a multicentre  
780 randomised controlled trial. *BMJ Open.* 2017;7(3).
- 781 **Reason for exclusion:** Background Article: Protocol with full study results available from included  
782 study [Borgen et al., 2019]
- 783 Bradley D, Landau E, Wolfberg A, Baron A. 500: Predicting the likelihood of developing gestational  
784 diabetes using data collected from a pregnancy mobile app. *Am J Obstet Gynecol.* 2019;220(1):S336.
- 785 **Reason for exclusion:** Ineligible population
- 786 Brough C, Schreder S, Northern A, Hadjiconstantinou M, Davies M, Khunti K. Development of a web-  
787 based prevention programme for women with post gestational diabetes (GDM): Baby steps. *Diabet  
788 Med.* 2019;36:100–1.
- 789 **Reason for exclusion:** Ineligible intervention: mHealth not the main intervention component
- 790 Cai M, Tan KH, Ang SB. I-ACT: Integrated study on effect of Activity on ComplicaTions in pregnancy:  
791 Study protocol of a multiethnic prospective cohort study. *BMJ Open.* 2019;9(4).
- 792 **Reason for exclusion:** Ineligible intervention: mHealth not the main intervention component

793 Caretto A, Rossi MG, Laurenzi A, Triberti S, Gandolfi A, Barrasso M, et al. The “active ageing” app:  
794 Preliminary usability evaluation of a mobile application for diabetes self-management. Diabetes  
795 Technol Ther. 2018;20:A116.

796 **Reason for exclusion:** Ineligible population

797 Cheung NW, Blumenthal C, Smith BJ, Hogan R, Thiagalingam A, Redfern J, et al. A pilot randomised  
798 controlled trial of a text messaging intervention with customisation using linked data from wireless  
799 wearable activity monitors to improve risk factors following gestational diabetes. Nutrients.  
800 2019;11(3):590.

801 **Reason for exclusion:** Ineligible intervention. mHealth not the main intervention component

802 Chan KL, Chen M. Effects of social media and mobile health apps on pregnancy care: Meta-analysis.  
803 JMIR mHealth uHealth. 2019;7(1).

804 **Reason for exclusion:** Ineligible source type: systematic review searched and no novel studies  
805 found

806 Chen Q, Carbone ET. Functionality, Implementation, Impact, and the Role of Health Literacy in Mobile  
807 Phone Apps for Gestational Diabetes: Scoping Review. JMIR diabetes. 2017;2(2):e25.

808 **Reason for exclusion:** Ineligible source type: scoping review, searched and no novel studies found

809 Collier J, Fortuin J, Adams S. Development of a gestational diabetes selfmanagement and remote  
810 monitoring mobile platform. J Diabetes Sci Technol. 2020;14(2):A24.

811 **Reason for exclusion:** Ineligible population

812 Ding B, Gou B, Guan H, Wang J, Bi Y, Hong Z. WeChat-assisted dietary and exercise intervention for  
813 prevention of gestational diabetes mellitus in overweight/obese pregnant women: a two-arm  
814 randomized clinical trial. Arch Gynecol Obstet. 2021;Epub ahead of print.

815 **Reason for exclusion:** Unable to access full text

- 816 Garg N, Shaima KA, Arora S, Kaur K. Application of Mobile Technology for Disease and Treatment  
817 Monitoring of Gestational Diabetes Mellitus Among Pregnant Women: A Systematic Review. J  
818 Diabetes Sci Technol. 2020.
- 819 **Reason for exclusion:** Ineligible source type; review searched and no novel studies found
- 820 Garnweidner-Holme L, Henriksen L, Torheim LE, Lukasse M. Effect of the Pregnant+ Smartphone  
821 App on the Dietary Behavior of Women With Gestational Diabetes Mellitus: Secondary Analysis of a  
822 Randomized Controlled Trial. JMIR mHealth uHealth. 2020;8(11):e18614.
- 823 **Reason for exclusion:** Ineligible source type
- 824 Gibson OJ, Loerup L, MacKillop L, Farmer AJ, Levy JC, Bartlett K, et al. GDm-health: Remote  
825 monitoring for gestational diabetes. J Diabetes Sci Technol. 2013;7(1):A51.
- 826 **Reason for exclusion:** Background article: full study included [Mackillop et al., 2018]
- 827 Hawkins M, Iradukunda F, Paterno M. Feasibility of a Sleep Self-Management Intervention in  
828 Pregnancy Using a Personalized Health Monitoring Device: Protocol for a Pilot Randomized  
829 Controlled Trial. JMIR Res Protoc. 2019;8(5):e12455.
- 830 **Reason for exclusion:** Ineligible population
- 831 Hirst JE, Mackillop LH, Loerup L, Farmer AJ, Kevat DA, Bartlett KJ, et al. GDm-health: Development  
832 of a real-time smartphone solution for the management of women with gestational diabetes mellitus  
833 (GDM). BJOG An Int J Obstet Gynaecol. 2015;122:403.
- 834 **Reason for exclusion:** Background article: full study included [Mackillop et al., 2018]
- 835 Honarvar B, Salehi F, Shaygani F, Hajebrahimi M, Homayounfar R, Dehghan S, et al. Opportunities  
836 and threats of electronic health in management of diabetes mellitus: An umbrella review of systematic  
837 review and meta-analysis studies. Shiraz E Med J. 2019;20(1):e81794.
- 838 **Reason for exclusion:** Ineligible population

839 Ilias I. Smartphones for gestational diabetes in the COVID-19 era. J Diabetes Metab Disord. 2021;3:1-  
840 2.

841 **Reason for exclusion:** Ineligible source type

842 Immanuel J, Simmons D. Apps and the Woman With Gestational Diabetes Mellitus. Diabetes Care.  
843 2021;44(2):313–5.

844 **Reason for exclusion:** Ineligible source type

845 Isrctn. Comparing continuous glucose monitoring with self-monitoring of blood glucose in gestational  
846 diabetes. [Internet]. 2018. [cited 2021 Mar 22]. Available from:  
847 <http://www.who.int/trialsearch/Trial2.aspx?TrialID=ISRCTN92877235>.

848 **Reason for exclusion:** Ineligible intervention: Not mHealth

849 Kalhori SRN, Hemmat M, Noori T, Heydarian S, Katigari MR. Quality evaluation of english mobile  
850 applications for gestational diabetes: App review using mobile application rating scale (mars). Curr  
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904 Diabetes. [Internet]. 2018. [cited 2021 Mar 22]. Available from:  
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914 Nct. The Effectiveness of Rt-CGM to Improve Glycemic Control and Pregnancy Outcome in Patients  
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1015 **Appendix III: Data extraction instrument**

Main category	Subcategory	Description
1. Authors		
2. Title		
3. Journal		
4. Year of publication		
5. Origin/country of origin		
6. Description of study	Type	Specify the type of study (e.g. Review, study protocol)
	Design	Specify the study design (e.g. RCT, qualitative study, quasi-experimental)
	Objective	Describe the study objective(s)
	Population	Describe the study population (e.g. at risk, pregnant, postpartum women) and their geographical location
	Outcome	State what the primary and secondary study outcomes are, where applicable
7. Intervention implementation	Comparator	Describe the comparator intervention used, where applicable
	Timing	Specify if the study states the timing of intervention implementation (e.g. Preconception, during pregnancy (weeks gestation), postpartum)
8. Description of the intervention	Context	Specify if the study focuses on intervention delivery in a particular care setting (e.g. Primary, secondary, community care) Describe how and by whom the intervention is delivered
	Type	Describe the type of intervention (e.g. app, wearable, social media,)
	Purpose	Describe the stated purpose of the intervention (e.g. Information giving, behavioral change, BGL monitoring, weight management)
	Length/intensity	Describe for how long and how often the intervention is delivered
	Theoretical background	Describe the theoretical background included in intervention development, where applicable
	Behavior change techniques	List of included behavior change techniques as categorized by the 26-item taxonomy developed by Michie and Abraham

<p>9. Key findings</p>	<p>Engagement</p> <p>Usage/adoption/adherence</p> <p>User experience</p> <p>Intervention feasibility</p>	<p>Describe where applicable, study findings on engagement of intervention (e.g. motivation to use intervention, time spent using intervention)</p> <p>Barriers and facilitators to intervention use/adoption among stakeholders</p> <p>Description of study reporting on user experience (e.g. satisfaction, perception)</p> <p>Barriers and facilitators to study implementation (e.g. recruitment, retention, study processes, study burden)</p>
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1016 **Appendix IV: Characteristics of included studies**

1017

Author/published year, country of origin / mHealth intervention	Study focus and design	mHealth type and purpose	mHealth features	Target population and sample	Outcome measures	Implementation context and duration of mHealth use	Behavior change theory and techniques	Key study findings
Borgen <i>et al.</i> <sup>30</sup> 2019 Norway Pregnant+ App	Evaluation  Multicenter <sup>a</sup> RCT  Intervention : App + standard care Control: standard care	App to support  <sup>b</sup> GDM self-management	- 'blood glucose' monitoring with real-time visualization  - Physical activity – written examples with images of how to perform activities  - Culturally	Pregnant women aged 18+, with 2-hour <sup>c</sup> OGTT >9 mmol/L who owned a smartphone  Intervention (n=112) Control (n=121)	Primary: postpartum <sup>d</sup> BGL 2hr OGTT at 3 months postpartum Secondary: induction of labor; mode of delivery; <sup>e</sup> NICU admission; Apgar Score; birth weight; infant feeding; cessation of breastfeeding; engagement with health via	App introduced at a diabetes outpatient clinic. Women downloaded the app themselves at hospital or at home. App used ≤33 weeks gestation to 3 months postpartum	Health Belief Model  1) Provides feedback on performance 2) Provide information about behavior-health link 3) Provides information on	Women who declined to take part (n=61), gave reasons such as too time consuming and no interest in the study. Large loss to follow up at 3 months postpartum meant the value and interpretation of findings is

			<p>adapted information about diet</p> <ul style="list-style-type: none"> <li>- Diabetes information – general info about GDM, follow-up and postpartum</li> <li>- Interaction with fHCPs is not possible but information from the app can be printed.</li> </ul>		app		<p>consequences and benefits</p> <p>4) Prompts self-monitoring</p> <p>Provides instruction</p>	restricted.
<p>Castorino <i>et al.</i><sup>31</sup> 2018 USA Tu Puedes App</p>	<p>Pilot study  Quasi experimental design</p>	<p>Culturally and linguistically appropriate</p>	<ul style="list-style-type: none"> <li>- 4 'lessons' about gT2DM prevention</li> <li>- Culturally</li> </ul>	<p>Latina women previously diagnosed with GDM aged 18-40</p>	<p>Primary: qualitative experience of using the app Secondary: self-</p>	<p>Not reported</p>	<p>1) Information about behavior-health link</p>	<p>Findings suggest satisfaction with app use and intention</p>



	with control Intervention : app use alone Control: classroom based education sessions	educational app for diabetes prevention among Latina women with previous GDM	applicable information	(n=22) Intervention: (n=not reported) Control: (n=not reported)	perceived health; weight; <sup>h</sup> BMI; waist circumference; blood pressure			among women to continue use.
Crimmins <i>et al.</i> <sup>32</sup> 2019 USA Glucose Mamma (App)	Evaluation Prospective RCT Intervention : app use alone Control: standard care	App to support GDM self-management	- Manual upload of BGL readings with real-time feedback - Text messages with positive feedback Information on healthy eating, recipes and meal plans	Pregnant women diagnosed with GDM at 24-34 weeks gestation. Intervention (n=13) Control (n=20)	Primary: Need to start pharmacologic therapy (metformin, glyburide and/or insulin). Secondary: compliance; no. of BGL readings logged; mode of delivery; shoulder dystocia; preeclampsia; birthweight;	App offered to women at a tertiary medical center. App used from diagnosis (24-34 weeks gestation) to delivery	1) Pro mpt self-monitoring of behavior 2) Provide feedback on performance	Findings suggest compliance among women with weekly log review when using the app.

					NICU admission; phototherapy; hypoglycemia; completed 2hr OGTT; initiated birth control; arrived at postpartum visit; breastfeeding at 6 weeks postpartum; weight loss at postpartum visit			
Dyson <i>et al.</i> <sup>33</sup> 2019 UK GDmHealth Plus App	Pilot study  Mixed methods evaluation	Mobile-phone based system for blood glucose management and behavioral lifestyle change during	See Mackillop <i>et al.</i> 2018 (GDmHealth app) for GDM self-management functions. - Weekly self-weighing - Carbohydrate	Pregnant women diagnosed with GDM (n=18)	System usage and satisfaction	App introduced to women at a large tertiary hospital. App used from diagnosis to delivery	1) Prompts self-monitoring behavior 2) Provide feedback on performance 3) Provides instruction	Findings suggest women interacted with the app and were satisfied with features aside from self-weighing and feedback about weight.

		pregnancy	<ul style="list-style-type: none"> <li>- counting</li> <li>- Physical activity monitoring</li> <li>- Real-time feedback on healthy behaviors via specialist dietician and midwives</li> </ul>					
Garnweidner-Holme <i>et al.</i> <sup>34</sup> 2015 Norway Pregnant+ App	Development and usability  User-centered iterative design and development process and think-aloud	See Borgen et al. 2019	See Borgen et al. 2019	Pregnant women diagnosed with GDM (n=21)	Design and develop an app	See Borgen et al. 2019	See Borgen et al. 2019	Findings suggest women's user experience was positive. Facilitators included making it easier to manage BGL and having real-time

	interviews.							feedback on levels. Inclusion of culturally appropriate information was also seen as key to adoption. Barriers included contradicting information between app and HCPs.
Ghaderi <i>et al.</i> <sup>35</sup> 2019. Iran Unnamed App	Evaluation  Quasi-experimental design with control group  Intervention : app + paper	Educational app to increase risk perception of T2DM among pregnant women with GDM	- Profile creation - Reminders for tests and medications - Video, photo and text education	Pregnant women with GDM diagnosis using insulin, aged 18-40, have android smartphone  Intervention: (n=44)	Primary: Risk perception of T2DM measured before and 6 weeks after intervention delivery	App introduced to women at university hospital. App was installed for women, and provided with a guidance booklet. App	1) Prompts practice 2) Provide information about behavior-health link 3) Provide information about	No findings regarding engagement or user experience available.

	based education  Control: paper based education		materials FAQ section regarding GDM and T2DM	Control: (n=43)		used for 6 weeks	consequence Provides instruction	
Guo <i>et al.</i> <sup>36</sup> 2019 China dNurse App	Evaluation  Single center RCT  Intervention : app use + standard care  Control: standard care	App to support GDM self-management	- Manual upload of BGL readings with real-time feedback - BGL data transmitted to HCP - HCP available to answer questions Provision of information on diet, exercise, treatment and GDM	Pregnant women with GDM diagnosis (fasting BGL $\geq 5.1$ mmol/L or 1HR OGTT $\geq 10.00$ mmol/L or 2hr OGTT $\geq 8.5$ mmol/L) aged 21-45 years, able to use smartphone Intervention (n=64) Control (n=60)	Outcomes: Compliance with BGL monitoring; frequency of outpatient service use; $\Delta$ HbA1c before delivery; mode of delivery; no. of off-target BGL measurements; shoulder dystocia; hypoglycemia in newborn; fetal macrosomia; $\Delta$ GA at delivery;	App offered to women at university hospital and downloaded the app themselves. App used from 24-28 weeks gestation to delivery.	1) Real-time feedback 2) Prompt self-monitoring of behavior 3) Information on health-behavior link 4) Provides instruction	Findings suggest women successfully used the app for recording their BGL.

					BLG measured by OGTT 3 months postpartum			
Hashmi <sup>37</sup> 2019 Oman SESSPA (App)	Trial registration  Feasibility RCT  Intervention : app use alone	App to support GDM self-management	<ul style="list-style-type: none"> <li>- health education content about GDM</li> <li>- goal setting and action planning</li> <li>- videos regarding recommended physical activities</li> <li>- video about the steps for blood glucose monitoring</li> <li>- photo</li> </ul>	Pregnant women with GDM diagnosis aged 18+ (n=15)	<p>Primary outcome: Feasibility measured by: rates of recruitment; retention rate; completion of intervention; participant satisfaction</p> <p>Secondary outcomes: Accessibility measured by: usage; focus groups</p>	App introduced to women at university hospital. App used from 22 – 30 weeks gestation until delivery	<ol style="list-style-type: none"> <li>1) Prompt intention formation</li> <li>2) Prompts practice</li> <li>3) Prompts self-monitoring behavior</li> <li>4) Provides feedback on performance</li> <li>5) Information on health-behavior link</li> <li>6) Informati</li> </ol>	N/A

			<p>examples of the recommended healthy diet</p> <ul style="list-style-type: none"> <li>- tracking of physical activity, diet and BGL</li> <li>- progress charts of daily self-reported data on healthy diet, physical activity and blood glucose monitoring.</li> <li>- text messages reminder</li> </ul>				<p>on on consequences</p> <p>7) Provides instruction</p>	
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			twice a day (8:00 am and 8:00 pm) to check their blood glucose level, maintain healthy eating, and maintain an active lifestyle.					
Hirst <i>et al.</i> <sup>38</sup> 2015; UK GDmHealth App	Pilot study Post questionnaire measuring satisfaction	See Mackillop <i>et al.</i> 2018	See Mackillop <i>et al.</i> 2018	Pregnant women with GDM diagnosis, not requiring pharmacological treatment (n=52)	Outcomes: Satisfaction with diabetes care; satisfaction with the GDmHealth system; relationship with diabetes care team	See Mackillop <i>et al.</i> 2018	See Mackillop <i>et al.</i> 2018	Findings suggest overall acceptability and satisfaction with app among women.
Jo and Park <sup>39</sup> 2016 Korea	Development and usability	App to provide tailored	App includes eight algorithms with	Pregnant women with GDM	Outcomes: Usability and acceptance	Women were recruited from an online	1) Prompts self-monitoring	Findings suggest women thought



Unnamed App	study  Mixed methods evaluation of usability and acceptability	interventions for GDM self-management.	18 decision nodes which enable the app to generate generic and tailored recommendations based on patient's data and clinical guidelines.	diagnosis Initial Usability (n=5) Further usability (n=60)		diabetes group to test the app at home. App used for 1 week	behavior 2) Provides feedback on performance	the app was useful but responses were mixed regarding acceptability including intention and motivation to use.
Kim <i>et al.</i> <sup>40</sup> 2021 South Korea (Virtual Reality)	Evaluation  Quasi-experimental study with control  Intervention : VR program use  Control: written educational	Mobile Virtual reality to support self-management to prevent type 2 diabetes	- 123 options of exercises - Nutrition program - Tracking of dietary intake with feedback on progress via graphs - Laughter therapy and deep	Postpartum women with prior GDM aged 20+ Intervention (n=57) Control (n=62)	Outcomes: Weight; body fat (%); fasting glucose level; HbA1C; diabetes knowledge; self-reported dietary habits; parenting stress; health promoting lifestyle behaviors	Women were asked to download and install the mobile VR program on their mobile phone the day before their scheduled delivery date or day after delivery. VR headsets were provided	1) Prompts self-monitoring behavior 2) Provides feedback on performance 3) Provides instruction 4) Model or demonst	No findings regarding engagement or user experience available.

	material		breathing for stress relief - Neonatal first aid program			to women at hospital delivery setting. How to use the equipment was demonstrated to women. VR use from birth for 12 weeks	rate behavior 5) Stress management	
Lechner <sup>41</sup> 2017 Germany Triangle App	Trial registration (Evaluation)  Parallel multi-center RCT  Intervention : app use Control: one-time written and in-person lifestyle	App to deliver lifestyle intervention program to reduce risk of T2DM among postpartum women with prior GDM	Not reported	Postpartum women with prior GDM (3-18 months ago) aged 18-50 (n=64)	Primary outcome: Proportion of women reaching 3 or more of the 5 Diabetes Prevention Program lifestyle aims at final study visit (6 months) which are: 150 mins of high intensity	Women commence app use at 3 – 18 months postpartum for 6 months of use	Not reported	N/A

	counselling				physical activity per week; 15g fiber; 30% of energy from fat; 10% energy from saturated fat; BMI Achievement of pre-defined nutrition, exercise and body weight Secondary outcomes: BGL from baseline to follow up; change of insulin sensitivity; BMI; $\dot{V}O_2$ peak; body fat mass; psychological wellbeing			
Lim <i>et al.</i> <sup>42</sup> 2021 Singapore	Evaluation  Single	App to support return to	- Track diet, exercise and	Postpartum women with prior GDM	Primary outcome: % of women	App introduced after delivery,	1) Prompt intention formation	Findings suggest that engagement

nBuddy app	center, open-label, RCT  Intervention : app use  Control: standard care (6 week postnatal check with dietary advice and repeat OGTT)	healthy weight	visualization of progress related to goals.  - Personalized educational information  - Real-time interaction with health and lifestyle coaches	diagnosis (between 24-34 weeks gestation), aged 21+.  Intervention (n=101) Control (n=99)	achieving first trimester weight at 4 months postpartum If previous booking weight $\leq 23 \text{ kg/m}^2$ OR weight loss of at least 5% of first trimester weight in BMI $>23 \text{ kg/m}^2$ .  Follow up at 6 weeks and 4 months.  Secondary outcome: Fasting BGL; HbA1c; mean weight loss; breastfeeding status; blood pressure; grip strength; waist circumference; caloric and	at University Hospital. Women asked to download the app and briefed on its use by a research assistant. App used for 4 months	2) Provides feedback on performance 3) Prompts self-monitoring 4) Information on health-behavior link 5) Provides instruction	with app was maintained at 4 month follow up.
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					macronutrient intake; self-efficacy; health education; well-being			
Loerup <i>et al.</i> <sup>43</sup> 2013 UK GDmHealth App	Pilot study  Feasibility of GDmHealth system in clinical practice including BG control and user satisfaction.	See Mackillop <i>et al.</i> 2018	See Mackillop <i>et al.</i> 2018	Pregnant women with GDM Used the system (n=41) Returned questionnaires (n=31)	Outcomes: Usage and satisfaction	See Mackillop <i>et al.</i> 2018	See Mackillop <i>et al.</i> 2018	Results suggest that overall app usage was high.
Mackillop <sup>44</sup> 2020 Stay Active App UK	Trial registration  Single Centre Feasibility study  Intervention	App to motivate women to increase activity levels during pregnancy	- Remote motivational interview - Simple interface to provide two-way communication with a	Pregnant women with GDM diagnosis, using the GDmHealth app to monitor BGL, aged 18-45,	Primary outcomes: adherence to wearing accelerometer; acceptability; physical activity (average daily minutes of total	Women offered app in hospital setting and will be shown how to use it. App used from 24-33 weeks	1) Prompt intention formation 2) Prompt-self monitoring of behavior 3) Provides feedback on	N/A

	: app use alone		<p>HCP to provide feedback on agreed goals.</p> <ul style="list-style-type: none"> <li>- Feedback is given via messages received via the app.</li> <li>- Physical activity goals can be reviewed within the app</li> </ul>	<p>have and use smartphone (n=60)</p>	<p>physical activity); recruitment rates</p> <p>Secondary:</p> <p>BGL from baseline to birth; physical activity time and intensity; attitude toward app and usefulness of components</p> <p>Maternal outcomes:</p> <p>weight at baseline to birth; need for pharmacological therapy; hypertension; GA at delivery</p> <p>Neonatal outcomes:</p> <p>birthweight;</p>	<p>gestation to 36-38 weeks gestation.</p>	<p>performance 4) Motivational interviewing</p>	
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					hypoglycemia; hyperbilirubinaemia; <sup>n</sup> SCUB admission; shoulder dystocia Health economic outcomes: no. of clinic visits; time spent by clinical midwife delivering intervention			
Mackillop <i>et al.</i> <sup>45</sup> 2018 UK GDmHealth App	Evaluation  Single center, non-blinded, parallel group RCT  Intervention : app use + standard care	Mobile-phone based system for blood glucose management	- Bluetooth Transfer of BG readings direct to app, with real-time feedback  - Meal details can be manually	Pregnant women with GDM diagnosis (via 75g OGTT), aged 18-45 yrs., with singleton pregnancy Intervention (n=103) Control	Primary: Rate of change in glycaemia (mmol/L28 days), from recruitment to delivery Secondary: maternal weight, BMI; hypertension; preeclampsia;	Women receiving care at large UK tertiary hospital were loaned a mobile phone with the preinstalled GDmHealth app and taught how to	1) Real-time feedback 2) Prompts self-monitoring 3) Provides instruction	Findings suggest women using the app were satisfied with their care and recorded their BGL using the app.

	Control: standard care		<p>attached to BG readings</p> <ul style="list-style-type: none"> <li>- Women can request a call back to discuss concerns with HCP.</li> <li>- HCPs can view BGL readings and meal tags via an online portal</li> </ul>	(n=103)	GA at delivery; birthweight; °LGA; birth mode; perineal trauma; shoulder dystocia; birth injury; neonatal hypoglycemia, neonatal hyperbilirubine mia; NICU admission	record, tag, and review blood glucose readings by a research midwife. App used at <35 weeks gestation to delivery		
Mackillop <i>et al.</i> <sup>46</sup> 2014 UK GDmHealth App	Developme nt and usability  Co-design followed by beta testing (focus groups) and	See Mackillop et al. 2018	See Mackillop et al. 2018	Pregnant women with GDM diagnosis, not requiring pharmacologi cal intervention. Beta testing	Outcomes: Usability and reliability	See Mackillop et al. 2018	See Mackillop et al. 2018	Findings suggest women used the app and complied with BGL monitoring.



	service development (capture of system usage data)			(n=7) Service development (n=50)				
Miremberg <i>et al.</i> 47 2018 Israel Glucose Buddy App	Evaluation  Prospective, Single center RCT  Intervention: app use + standard care  Control: standard care	Mobile-phone based system for blood glucose management	- Manual upload of BGL measurement - Daily reports of BGL emailed to HCP - Individualized feedback on BGL emailed to women daily - Emails also include positive messaging, dietary tips, modifications to insulin treatment, and appointment scheduling - Interaction with HCP	Pregnant women with GDM (fasting $\geq 95$ mg/dL, 1-hour $\geq 180$ mg/dL, 2-hour $\geq 155$ mg/dL, 3-hour $\geq 140$ mg/dL) aged 18-45 years Intervention (n=60) Control (n=60)	Primary: Compliance with BGL monitoring Secondary: mean BGL; need for insulin therapy; % of off target BGL measurements; polyhydramnios; preeclampsia, hypertension; mode of delivery; shoulder dystocia; perineal trauma; birthweight; LGA; NICU admission;	App offered at diabetes in pregnancy clinic at tertiary hospital. All women received a 10 minute demo regarding the use of the app alongside an information leaflet. App used form diagnosis (<34 weeks gestation) to delivery	1) Personalized feedback 2) Prompt to self-manage 3) Provides instruction	Findings suggest compliance with BG monitoring and satisfaction among women using the app.

			regarding questions about GDM management		infant hypoglycemia; phototherapy; respiratory morbidity; neonatal death; composite adverse neonatal outcome			
O'Reilly <i>et al.</i> <sup>48</sup> 2019 Australia Health-e mums Program (App with virtual coaching and social media)	Pilot study  User-centered - qualitative focus groups	App for T2DM prevention in women with prior GDM	<ul style="list-style-type: none"> <li>- Tracks weight, exercise and dietary intake</li> <li>- Provides T2DM screening results</li> <li>- Personalized push notifications regarding feedback on body weight,</li> </ul>	Postpartum women with prior GDM (n=26)	Feedback on functionality and user experience	N/A	<ol style="list-style-type: none"> <li>1) Prompts self-monitoring behavior</li> <li>2) Provides feedback on performance</li> <li>3) Provides opportunities for social comparison</li> </ol>	Facilitators for perceived app use included the app being a reliable and credible source of information that was conveniently accessible. The connection with Facebook was seen as a positive way to connect with other

			<p>diet, and physical activity progress</p> <ul style="list-style-type: none"> <li>- Virtual health coach guides through seven educational modules</li> </ul>				<p>4) Prompts practice</p> <p>5) Prompt intention formation</p> <p>6) Information on health-behavior link</p> <p>7) Provides instruction</p>	<p>postpartum women.</p> <p>Barriers to perceived app use included the usefulness of video segments and applying milestones related to diabetes prevention guidelines.</p>
<p>Pais <i>et al.</i> <sup>49</sup> 2017</p> <p>New Zealand My Meal Mate (App) Glucose Buddy (App) On Track (App) Doctor Diet (App) HealthVault (App)</p>	<p>Pilot study</p> <p>Qualitative interviews / focus groups</p>	<p>Five commercially available health and wellness apps to aid self-management</p>	<p>Apps had a mixture of functionalities including food diaries, exercise tracking, glucose monitoring and ability to export data to clinicians.</p>	<p>Pregnant women with GDM diagnosis (n=5)</p>	<p>Outcomes:</p> <p>Perceived usefulness and perceived ease of use</p>	<p>N/A</p>	<p>1) Prompts self-monitoring behavior</p>	<p>Findings suggest women perceived the ecosystem of apps to be useful.</p> <p>Facilitators for use included sharing data with clinicians and control</p>

								over access of data.
Poulter <sup>50</sup> 2019 Australia Net Health (App)	Trial registration (Pilot)  Non-randomized trial  Intervention : app use  Control: historical control using standard care	App to support self-management of blood glucose levels	- Automatic upload of BGLs in real time to a secure server for review remotely by clinicians.  - Automatically generates email alert to clinicians if BGLs are out of target range.  - Allows messaging from HCPs to women	Pregnant women with GDM diagnosis, aged 18-45, singleton pregnancy, has and uses smartphone  Intervention (n=100)  Control (n=100)	Primary outcome; Feasibility (clinic workload); acceptability and patient satisfaction; usage of the system  Secondary outcomes: mean weekly BGL; composite neonatal outcomes.	App introduced at diabetes services clinics. The app contains some instructions about its use and women will have direct contact details for the diabetes educators to obtain support. App used from 24-30 weeks gestation to delivery	1) Prompts self-monitoring behavior  2) Provides feedback on performance  3) Provides instruction	N/A

			via the app for dose titration where required.					
Pustozarov <i>et al.</i> 51 2017 Russia Unnamed App	Pilot study  App usage data and post study survey	Mobile system for personalized blood glucose prediction	<ul style="list-style-type: none"> <li>- BGL readings automatically uploaded via continuous glucose monitoring system</li> <li>- Logging of dietary intake</li> <li>- In-built algorithm provides personalized advice regarding upcoming meals</li> </ul>	Pregnant women with GDM (n=138)	System usage and patient satisfaction	N/A	<ul style="list-style-type: none"> <li>1) Provides feedback on performance</li> <li>2) Prompts self-monitoring behavior</li> </ul>	<p>Findings suggest usage of the app among women .Facilitators to using the app were convenience and helpful information. Barriers to usage included lack of food items in the food database when logging meals.</p>

			based on BGL.					
Rawal and Peters <sup>52</sup> 2019 Nepal mGDM (App)	Trial registration  User-centered design + Parallel open label RCT  Intervention : app use + standard care  Control: standard care	App for increasing knowledge and self-efficacy to adhere to healthy lifestyle behaviors	- Health education - Identification and setting of health goals Facilitates support from family members	Pregnant women with GDM diagnosis aged 18+ (n=60)	Primary outcomes: maternal BGL at 6 weeks postpartum; birth weight; mode of delivery; app usage; adherence to BGL monitoring; usability; acceptability	App introduced to women at sub-urban tertiary level university hospital. App will be set up for women on their smartphone. App used from 28 weeks gestation to delivery – maximum of 16 weeks	Social cognitive theory  1) Prompt intention formation 2) Provide opportunities for social comparison 3) Provide information about behavior health link	N/A
Rigla <i>et al.</i> <sup>53</sup> 2017 Spain	Pilot study  Survey and	AI augmented mobile	- Automatic upload of BGL - Messaging	Pregnant women with GDM	Outcomes: Compliance with BGL	App introduced to women at	1) Prompts self-monitoring	Findings suggest the system to be

MobiGuide App	Observational prospective study  Intervention : app use  Control: historical control of standard care users	system for GDM self-management	system with HCPs to provide personalized advice regarding meals and BGL - Embedded accelerometer to track physical activity	diagnosed aged 18+ Intervention (n=20) Control (n=247)	monitoring; satisfaction; blood pressure; need for insulin therapy; BGL; GA delivery; Mode of delivery; birth weight; LGA	hospital setting. App used from diagnosis (34 weeks gestation) to delivery	behavior 2) Provides feedback on performance	feasible and acceptable among women who were compliant with BGL monitoring when using the app.
Seely <i>et al.</i> <sup>54</sup> 2020 USA Hola Bebe, Adios Diabetes! App	Pilot study  Development, feasibility and preliminary effectiveness  Intervention : app use alone	App to reduce risk factors associated with T2DM progression among Hispanic women	- Six audio-visual educational modules on healthy eating and physical activity - personal action plans for healthy eating and	Postpartum women with GDM diagnosis in past 5 years, aged 18-45. Acceptability (n=11) Usability (n=4) Pilot (n=21)	Outcomes: Acceptability and usability	A research assistant helped women to download the app and review the 'how-to section'. Women were asked to complete one module,	Social cognitive theory 1) Provide contingent rewards 2) Provide information about behavior-health link 3) Provide	Findings suggest the app to be acceptable and usable for women. Facilitators included features such as audio-visual modules, badges, weight-tracking

			<ul style="list-style-type: none"> <li>- staying active</li> <li>- Educational and motivational messages targeting self-efficacy</li> <li>- weight tracking</li> <li>- recipes</li> <li>- tiered badges to reward achievements</li> </ul>			<p>corresponding action plan, weigh themselves and enter this into the app at app introduction. App used for 8 weeks</p>	<p>instruction 4) Prompt-self monitoring of behavior 5) Prompt specific goal setting 6) Prompt intention formation</p>	<p>graphics and recipe features most useful. Findings from app data suggest good levels of engagement with the app over 8 weeks of use.</p>
<p>Skar <i>et al.</i> <sup>55</sup> 2018 Singapore Pregnant+ (App)</p>	<p>Evaluation (qualitative)  Qualitative process evaluation (nested in RCT)</p>	<p>See Borgen et al. 2019</p>	<p>See Borgen et al. 2019</p>	<p>Pregnant women with GDM diagnosis who had been allocated to the intervention</p>	<p>Outcomes: Understand women's experiences of using the Pregnant+ app</p>	<p>See Borgen et al. 2019</p>	<p>See Borgen et al. 2019</p>	<p>Barriers to usage included technological difficulties, feelings of obsession around BGL monitoring and</p>



	Borgen et al. 2019)			arm of the RCT (n=17)				frustration at differences in information between the app and HCPs. Findings overall suggest mixed levels of engagement with the app.
Sung <i>et al.</i> <sup>56</sup> 2019 Korea Unnamed App	Pilot study  Pilot, single center RCT  Intervention ; mHealth use + standard care  Control: standard care	Mobile system to support GDM self-management	<ul style="list-style-type: none"> <li>- Automatic upload of BGL readings</li> <li>- BGL data transmitted to clinical team who provide feedback via app 2x per week</li> <li>- Recoding of dietary intake</li> <li>- Interaction</li> </ul>	Pregnant women with GDM diagnosis with singleton pregnancy Intervention (n=11) Control (n=10)	Obstetric outcomes: GA at delivery; LGA; C-section rate Maternal outcomes: BMI; weight; % of body fat; OGGT result at 5-12 weeks postpartum	App introduced to women at hospital setting and were trained on how to use the device on assignment. App used from 24-28 weeks gestation until delivery	<ol style="list-style-type: none"> <li>1) Prompts self-monitoring behavior</li> <li>2) Provides feedback on performance</li> <li>3) Provides instruction</li> </ol>	No findings regarding engagement or user experience available.

			with HCP who send tailored medical and nutritional guidance via in-app messages.					
Varnfield <i>et al.</i> <sup>57</sup> 2020 Australia MOTHer App	Pilot study  Feasibility, satisfaction and preliminary effectiveness  Intervention : app use alone	App for remote management of blood glucose levels	- Manual upload of BGL readings - BGL readings viewed by HCP via online portal  Interventions are tailored based on BGL data	Pregnant women with GDM diagnosis aged 16+. (n=40)	Primary outcome: Usage (number and frequency of BGL readings uploaded); user satisfaction.  Secondary outcomes: comparison with historical data regarding: no. of clinical reviews; frequency of antenatal contact; need for	App introduced to women after referral from GP to antenatal care maternity services. App used from 24-28 weeks gestation to delivery	1) Prompts self-monitoring behavior 2) Provides feedback on performance	Findings indicate satisfaction with the app. Facilitators to app use included easy access and convenience. Barriers included technological issues with connectivity.

					pharmacological treatment; service usage.			
Wickramasinghe <i>et al.</i> <sup>58</sup> 2019 Australia DiaMOnd App	Evaluation  2x2 un-blinded, single center, cross-over trial  Intervention : App + standard care  Control: standard care	Mobile-based system for blood glucose self-management and monitoring	- Manual upload of BGL reading  - BGL readings sent to HCP who provide real-time feedback and recommendations for diet, exercise and insulin titration  - System keeps a log of diet, physical activity and	Pregnant women with GDM Diagnosis (n=10)	Outcomes: proof of concept; usability; fidelity measured by: patient compliance; patient satisfaction; level of glycemic control achieved; health professional satisfaction	4 weeks	1) Real-time feedback 2) Prompts self-monitoring behavior 3) Provides instruction	Findings suggest women were satisfied with the app. Motivation for using the app was focused on doing the best for their baby. Facilitators for use included the inclusion of a food diary, recommendations for exercise and voice recognition to avoid data entry burden. Facilitators also included

			insulin use for future review					receiving support to use the app by HCPs.
Yew <i>et al.</i> <sup>59</sup> 2020 Singapore Habits GDM App	Evaluation  Parallel, open label, single center RCT  Intervention : app use + standard care  Control: standard care alone	App to promote behavior change during pregnancy for a healthy lifestyle	- Tracks diet and physical activity - Provides lifestyle coaching via in app messaging - Interactive lessons to support patient education	Pregnant women with GDM (WHO 2013 criteria) aged 21+, had smartphone, Intervention: (n=170) Control: (n=170)	Primary outcome: Proportion of women with excessive gestational weight gain; Secondary outcomes: adherence to BG monitoring; BG control; no of off target BG measurements; requirement of pharmacological therapy; Maternal outcomes: hypertension; preeclampsia delivery and	App introduced at national university hospital and used from 12-30 week's gestation diagnosis.	1) Prompts self-monitoring behavior 2) Provide feedback on performance 3) Information on health-behavior link 4) Provides instruction	No findings regarding engagement or user experience available.

					neonatal outcomes			
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1019 <sup>a</sup>RCT – randomized control trial

1020 <sup>b</sup>GDM – gestational diabetes

1021 <sup>c</sup>OGTT – oral glucose tolerance test

1022 <sup>d</sup>BGL – blood glucose level

1023 <sup>e</sup>NICU – neonatal intensive care unit

1024 <sup>f</sup>HCP – health care professional

1025 <sup>g</sup>T2DM – type 2 diabetes mellitus

1026 <sup>h</sup>BMI – body mass index

1027 <sup>j</sup>HbA1C - glycated hemoglobin

1028 <sup>k</sup>GA – gestational age

1029 <sup>l</sup>VR – virtual reality

1030 <sup>m</sup>V02 – oxygen uptake

1031 <sup>n</sup>SCUB – special care baby unit

1032 °LGA - large for gestational age