Systematic Review of Lifestyle Interventions for Gestational Diabetes Mellitus in Pregnancy and the Postpartum Period

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Abstract

Objective: To examine the characteristics and effectiveness of lifestyle interventions for gestational diabetes mellitus (GDM) in pregnancy and the postpartum period to prevent Type 2 diabetes.

Data Sources: We conducted searches in seven databases, including Ovid MEDLINE, CINAHL, Ovid Embase, Cochrane Central, Web of Science, Ovid Psyclnfo, and ProQuest Dissertations and Theses for articles published from inception to January 2021.

Study Selection: We included articles on controlled intervention studies in which researchers evaluated a lifestyle intervention provided during pregnancy and the postpartum period for women with or at risk for GDM that were published in English.

Data Extraction: Twelve articles that were reports of seven studies met the inclusion criteria. In some cases, more than one article was selected from the same study. For example, articles reported different outcomes from the same study. We extracted data with the use of a data collection form and compared and synthesized data on study design, purpose, sample, intervention characteristics, recruitment and retention, and outcomes.

Data Synthesis: All seven studies focused on weight management and/or healthy lifestyle behaviors (diet and physical activity). Outcomes included glucose regulation, weight, lifestyle behaviors, and knowledge. The interventions varied in duration/dosage, strategies, and modes of delivery. In four studies, researchers reported interventions that had significant effects on

improving glucose regulation and/or weight change. Some characteristics from the four effective interventions included goal setting, individualized care, and good retention rates. In the other three studies, limitations included low rates of participant retention, lack of personalized interventions, and limited population diversity or lack of culturally sensitive care.

Conclusion: Lifestyle interventions provided during and after pregnancy to reduce the risk associated with GDM have the potential to improve outcomes. Health care counseling to promote healthy lifestyle behaviors related to the prevention of Type 2 diabetes is needed at different stages of maternity care for women with GDM. Additional high-quality studies are needed to address the limitations of current studies.

Keywords

diabetes prevention; gestational diabetes; lifestyle; postpartum period; pregnancy; systematic review

Gestational diabetes mellitus (GDM) is one of the most common complications during pregnancy. In 2013, the estimated prevalence of GDM was 14.2% globally (Guariguata et al., 2014); it was 6% in the United States in 2016 (Deputy et al., 2018). Many short-term consequences have been related to GDM, including poorer pregnancy and neonatal outcomes (Farrar et al., 2016). In the long term, women with histories of GDM had a 10-fold risk of progressing to Type 2 diabetes (T2D) compared to those without histories of the disease (Vounzoulaki et al., 2020). Women with prior GDM had up to a 58% chance of developing T2D in their lifetimes (Li et al., 2020), and the greatest risk occurred within 3 to 6 years after the index pregnancy in which GDM occurred (Song et al., 2018). Therefore, women with histories of GDM tended to develop T2D early during their reproductive years, which indicates a longer duration of disease, greater risk for cardiovascular complications, and poorer quality of life (Dali et al,, 2014; Song et al., 2018). In general, a GDM diagnosis provides a key opportunity to promote lifestyle change and provide lifestyle interventions.

Lifestyle interventions can be very effective to prevent diabetes among women with histories of GDM (Aroda et al., 2015). Traditionally, lifestyle interventions for women with GDM have been provided during pregnancy or the postpartum period (Li et al., 2020). Lifestyle interventions during pregnancy were effective to improve glucose regulation to reduce perinatal negative outcomes for mothers and infants (Bgeginski et al., 2017; Brown et al., 2017; Yamamoto et al., 2018), whereas the effect for reducing the long-term risk of T2D was inconclusive (Li et al., 2020). Lifestyle interventions provided in the postpartum period were associated with reducing diabetes-related risk factors (e.g., insulin resistance and weight reduction; Goveia et al., 2018; Guo et al., 2016) and the long-term risk of T2D by 43% (Li et al., 2020). However, we found no systematic review on lifestyle interventions related to GDM provided during pregnancy and the postpartum period.

Although lifestyle interventions provided in the postpartum period are effective to improve health outcomes, researchers reported challenges to providing postpartum-only lifestyle interventions for women with histories of GDM in clinical practice. For example, in the postpartum period, women with GDM expressed a sense of abandonment after the intense treatment and management of GDM during pregnancy (Van Ryswyk et al., 2015).

In addition, researchers reported little attention to maternal health, health behaviors, and glycemic regulation after birth (LaManna & Quelly, 2020). Standard follow-up after birth includes only one visit at approximately 6 weeks to evaluate glucose regulation (American College of Obstetricians and Gynecologists, 2018). Women reported a lack of proactive approaches to prevent T2D in the postpartum period (Van Ryswyk et al., 2015), which suggests a low priority for T2D prevention (Nielsen et al., 2014). In many countries (including the United States), women with histories of GDM lack continuous care in the postpartum period to support T2D prevention because of fragmented health care systems. It is unclear whose primary responsibility it is to provide care to prevent T2D for women with histories of GDM in the postpartum period. Potential providers could be obstetricians, midwives, pediatricians, or primary care providers (Wilkinson et al., 2014). In addition, the demands of caring for a newborn limit mothers' time to participate in lifestyle interventions during the postpartum period (Buelo et al., 2019; Jones et al., 2017).

Recent lifestyle interventions for GDM are targeted to pregnancy and the postpartum period. Researchers suggested that it is ideal to have a GDM intervention program extend beyond pregnancy into the postpartum period to improve engagement in lifestyle change (Jones et al., 2017). Pregnancy uniquely creates a "teachable moment" because the mother is highly motivated to improve her health for the benefit of the infant (Phelan, 2010). Innovative lifestyle intervention programs that start during pregnancy and continue into the postpartum period may have an effect on T2D risk after birth (Jones et al., 2017). Lifestyle interventions during pregnancy and the postpartum period have important advantages for women with GDM. First, the initial years after the index pregnancy with GDM can be most valuable for T2D prevention because the speed of conversion to T2D is fastest within 3 to 6 years of the index pregnancy (Song et al., 2018). Second, the reduced focus on healthy lifestyle behaviors between pregnancy and the postpartum period should be avoided. Researchers have suggested that lifestyle interventions provided within 6 months of birth are more effective than programs started later (Goveia et al., 2018). Finally, lifestyle interventions that incorporated consistent and repeated messaging on diabetes prevention during pregnancy showed greater reach and recruitment yield compared to postpartum-only programs (Dasgupta et al., 2018).

Continuous care for women with or at high risk for GDM through lifestyle intervention programs during pregnancy and the postpartum period may be a potentially promising approach to prevent T2D. Therefore, the aims of our review were to examine the characteristics and effectiveness of lifestyle interventions for GDM in pregnancy and the postpartum period to prevent T2D.

Methods

We used the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines (Moher et al., 2009) to guide our article screening, selection, and reporting of the findings.

Search strategy

We designed and conducted a systematic search with assistance from medical librarians. We used a Medical Subject Headings analysis of four articles to inform our search strategy (Grossetta Nardini & Wang, 2020). We searched the following databases: Ovid MEDLINE, CINAHL, Ovid Embase, Cochrane Central, Web of Science, Ovid Psyclnfo, and ProQuest Dissertations and Theses for articles from inception to January 2021. We set no limitation on the start date because we expected a small number of eligible articles. Controlled vocabulary supplemented with keywords was used to define the concept areas of "gestational diabetes mellitus," "lifestyle behaviors," "physical activity," "diet," "nutrition," and "self-management." We adjusted the search strategies for the syntax appropriate for each database/platform and limited the search to articles published in English. We hand-searched studies with a published protocol for their results manuscript (e.g., using the trial registration number). We also contacted the authors of protocols for information on any additional publications. Relevant reference lists were also purposefully searched. We imported results into EndNote, version X8, and removed duplicates. A total of 3,146 references were initially retrieved, and after the removal of duplicates, 1,754 references remained. We uploaded the final set into Covidence systematic review software for screening. The complete search strategy from MEDLINE is attached in Supplementary Table S1.

Eligibility criteria

We included articles that met the following inclusion criteria: (a) reported studies on women with GDM, with histories of GDM, or at increased risk for GDM; (b) had interventions that were provided during pregnancy and the postpartum period and included a lifestyle or self-management intervention to prevent T2D; (c) included outcomes related to behavioral changes (e.g., physical activities, diet), glucose tolerance status, or weight status; (d) reported studies that were controlled clinical trials (e.g., randomized controlled trial [RCT] or quasi-experimental design with control group); and (e) reported the results of the study. We excluded studies of women with preexisting Type 1 diabetes and T2D or pharmacologic interventions, as well as studies that focused only on the prevention of GDM before the diagnosis of GDM. We defined the postpartum period as the time frame from birth to 12 months after birth.

Study selection

Two reviewers (S.H. and C.M.-N.) independently screened all the titles and abstracts in Covidence and applied the eligibility criteria to select articles for full-text review. Any discrepancies between the two reviewers were discussed until consensus was reached. Subsequently, the two reviewers (S.H. and C.M.-N.) independently reviewed the full-text articles, and discrepancies were discussed with the senior reviewer (R.W.) until consensus was reached. When there were several articles from one study, we combined data from these sources.

Data extraction

We extracted data on study design, purpose, inclusion and exclusion criteria, participant characteristics, components of the interventions, recruitment, retention, and study results.

For studies with multiple articles, we extracted the key data points for the study. If there were conflicting data among the different articles for the same study (e.g., recruitment or retention rates), we presented the data from the article reporting the primary outcomes of the study. The primary reviewer (S.H.) conducted data extraction independently, and the second reviewer (C.M.-N.) reviewed the extracted data independently. Any discrepancy was discussed by the two reviewers with guidance from the senior reviewer (R.W.) until consensus was reached.

Risk of bias

To ensure the quality of each selected article, we assessed the risk of bias using two tools: Risk of Bias 2, which is the revised Cochrane tool for assessing the risk of bias in randomized trials (Sterne et al., 2019), and the National Heart, Lung, and Blood Institute Quality Assessment of Controlled Intervention Studies tool (2020) for the quasi-experimental studies). Two reviewers (S.H. and C.M.-N.) independently assessed each article and discussed discrepancies until reaching a consensus. The senior reviewer (R.W.) was consulted for the selection of tools and resolving any discrepancies.

Data synthesis

To facilitate data synthesis, we created a summary sheet with the key characteristics of the included studies and summarized the results, including participant characteristics, participation, attrition, and outcomes (see Supplementary Table S2). We also identified similarities and differences related to intervention components (see Supplementary Table S3). All authors reviewed and discussed the data extraction tables and synthesized results.

Results

Study selection process

We identified 1,754 records from the databases and other sources. After the title and abstract screening, we excluded 1,687 of the 1,753 records because they did not meet the eligibility criteria. We completed a full-text review of the remaining 67 articles. Reasons for excluding articles are listed in the PRISMA flow chart (see Figure 1). Twelve articles from seven studies met the inclusion criteria for this review.

Study characteristics

The characteristics of the seven studies are identified in Supplementary Table S2. Six studies were RCTs, one was a quasi-experimental design, and all were published between 2011 and 2020. Four studies were pilot or feasibility trials, two were efficacy trials, and one was a pragmatic RCT. Five of the seven studies focused on women with GDM, whereas two studies included women with GDM and women with a high risk for GDM. All seven studies were conducted in developed countries, including the United States ($n = 5$), Australia ($n = 1$), and Finland ($n = 1$). Sample sizes ranged from 25 to 1,783 with a total of 2,569 women across the seven studies.

In five studies, participants were of diverse race/ethnicity; however, in four of these studies, there was a dominant racial/ethnic group, including Asian women ($n = 3$; Cheung et al.,

2019; Ferrara et al., 2011, 2016) and African American women ($n = 1$; Berry et al., 2016). For the other two studies, participants were Hispanic women (Palnati et al., 2021) and White women in Finland (Huvinen et al., 2018). In the study of Hispanic women, a culturally tailored intervention was specified (Burkart et al., 2020; Chasan-Taber et al., 2014; Palnati et al., 2021). The mean age of participants across studies was 27 to 34 years (the age range of all participants was 16 to 50 years). In the studies with Asian women as the dominant racial/ethnic group, participants had an average prepregnancy body mass index (BMI) of less than 30 kg/m^2, whereas the women in the other studies had an average prepregnancy BMI of greater than 30 kg/m^2.

Risk of bias

We determined that only one of the six RCTs had a low risk of bias, whereas the other five had some risk of bias (see Supplementary Table S4). In research on lifestyle interventions, it is not possible to blind participants and trial personnel, but it is possible to blind outcome assessors, and we considered the latter in our risk of bias assessment. We deemed the quasi-experimental study as low quality using the National Heart, Lung, and Blood Institute tool because of the small sample size, unequal group size (18 in the treatment group vs. 5 in the control group), nonrandom group assignment, and no information on blinding for the outcome assessors.

Intervention characteristics

Overall characteristics.—In all seven studies, researchers provided lifestyle interventions during pregnancy and the postpartum period. Control groups in these studies received one of the following: attention control with the same contact time as the intervention group (Amason et al., 2016; Huvinen et al., 2018; Palnati et al., 2021), usual care (Ferrara et al., 2011, 2014), a wait-list control while receiving usual care (Berry et al., 2013), or written information (Cheung et al., 2019). In five of the intervention studies, researchers used a theory to guide the intervention protocol (see Supplementary Table S2). Intervention strategies included personalized goals, motivational interviewing, and self-monitoring (see Supplementary Table S3). Two of the interventions were based on the National Diabetes Prevention Program (DPP) and were conducted by researchers in the Kaiser Permanente Medical Care Program of Northern California (KPNC; Ferrara et al., 2011, 2016); one of these studies was a health system level pragmatic trial (Ferrara et al., 2016). In most of the intervention studies, care providers in the intervention group were able to tailor strategies or goals to the individual participant.

Pregnancy interventions.—The intervention protocols during pregnancy varied. The number of sessions ranged from one to three sessions or more. One intervention included sessions throughout the pregnancy (Huvinen et al., 2018), whereas the other interventions started in the third trimester after GDM screening and diagnosis (Amason et al., 2016; Berry et al., 2013; Cheung et al., 2019; Ferrara et al., 2011, 2014; Palnati et al., 2021). During pregnancy, the most interventions focused on lifestyle behaviors and/or weight management (Amason et al., 2016; Cheung et al., 2019; Ferrara et al., 2011, 2014; Huvinen et al., 2018; Palnati et al., 2021), and one intervention focused on breastfeeding (Berry et al., 2013). Gestational weight gain goals were specified in four interventions (Ferrara et al., 2011,

2014; Huvinen et al., 2018; Palnati et al., 2021). Dietary and physical activity goals specific for the stage of pregnancy were specified in two interventions (Cheung et al., 2019; Ferrara et al., 2011). Intervention components provided during pregnancy were delivered by group sessions, individual appointments, information sent by mail, or a combination of several delivery modes.

Postpartum interventions.—Interventions provided during the postpartum period were from 3 weeks to 12 months after birth. The number of sessions ranged from one to more than 10, and follow-up time was aligned with the duration of the intervention. All interventions targeted a healthy diet and physical activity. The guidelines for a healthy diet were heterogeneous, whereas the guidelines for physical activity were more consistent across studies. Postpartum weight management goals were specified in five studies and were similar among the studies. In most interventions, a combination of behavioral strategies was used, with goal setting as the most popular strategy. The mode of delivery for the interventions included individual in-person visits only (Huvinen et al., 2018); telephone only (Amason et al., 2016); weekly face-to-face group sessions plus text messages (Berry et al., 2013); adaptive text messages (Cheung et al., 2019); or multimodal interventions such as in-person plus telephone (Ferrara et al., 2011); telephone plus mail (Ferrara et al., 2016); and in-person, telephone, and mail (Palnati et al., 2021).

Recruitment, attendance, and retention.—Recruitment rates of eligible women ranged from 28%–78% (see Supplementary Table S2; Ferrara et al., 2011, 2016; Palnati et al., 2021). Among the three articles that reported attendance, the attendance was between 60% and 80% (Berry et al., 2016; Ferrara et al., 2011; Huvinen et al., 2018). In the pragmatic RCT, approximately half of the women attended one or more of the available 13 telephone sessions (Ferrara et al., 2016). Excellent retention rates (70%) were shown in four of the six studies that lasted at least 38 weeks postpartum (Ferrara et al., 2011, 2014; Huvinen et al., 2018; Palnati et al., 2021). Two other studies that lasted at least 28 weeks postpartum had lower retention rates (45% 51%; Berry et al., 2016; Cheung et al., 2019). The rates of attrition were greatest for most studies during the early postpartum time, at 6-week postpartum or 6-month postpartum follow-up visits.

Intervention results

Outcomes evaluated included glucose regulation, weight, physical activity, diet, and knowledge (see Table 1). In four studies, researchers reported significant improvements in glucose regulation and/or weight change (Ferrara et al., 2011, 2016; Huvinen et al., 2018; Palnati et al., 2021). Huvinen et al. (2018) reported that the percentage of women who presented with impaired fasting glucose, impaired glucose tolerance, or T2D was significantly lower in the intervention group during the first 12 months postpartum compared to a control group ($OR = 0.18$, 95% confidence interval [0.05, 0.65]). Ferrara et al. (2016) reported that a significantly greater percentage of women in the intervention group met their postpartum weight loss goals at 12 months postpartum compared to women in the control group. A reduction in the development of T2D or prediabetes was seen in the intervention group at postpartum diabetes screening; however, this reduction was not statistically significant. Ferrara et al. (2011) reported that 16% more participants in the

intervention group reached their postpartum weight reduction goal at 12 months postpartum ($p < .05$), and the effect was more significant among the women who reached their gestational weight gain goals. Palnati et al. (2021) reported significantly greater odds ($OR=$ 2.52, 95% confidence interval = [1.09, 5.82]) of returning to prepregnancy weight among women in the intervention group 12 months postpartum compared to women in the control group. Also, women with higher levels of physical activity had more significant weight loss.

These four interventions affected other outcomes, including dietary behavior change (Ferrara et al., 2011; Huvinen et al., 2018) or physical activity (Ferrara et al., 2016; Palnati et al., 2021). In two studies, researchers found significant effects on only one outcome: dietary behavior (Berry et al., 2016) or knowledge (Amason et al., 2016). Cheung et al. (2019) reported no effects on outcomes.

Unique characteristics of the four interventions affected glucose regulation or weight change. First, goal setting was used in all four interventions. Goals included clear weight management goals for pregnancy and the postpartum period and dietary and physical activity goals in the postpartum period (Ferrara et al., 2011, 2016; Huvinen et al., 2018; Palnati et al., 2021). Next, individualized care as a multimodal intervention (e.g., telephone and mail) or an in-person lifestyle counseling program was included in successful interventions during pregnancy and the postpartum period. In addition, these studies had large sample sizes ($N = 197–1,783$) with excellent retention rates (70%–85%). Furthermore, three of the four studies (two U.S.-based studies and the Finnish study) were carried out in a large integrated health care system that included primary care delivery and prenatal care. The three U.S. studies were similar in their postpartum intervention characteristics: most intense intervention sessions during the first 6 months postpartum (two studies were DPP-driven) and a combination of different delivery modes.

Other intervention characteristics differed among these four studies. For instance, the number of intervention sessions and delivery routes varied during pregnancy; Huvinen et al. (2018) focused on three in-person counseling sessions in pregnancy, in contrast to Ferrara et al. (2016), who used one tailored mail delivery strategy in pregnancy. Participant characteristics differed among the four studies: two studies (Ferrara et al., 2011, 2016) had samples with a large number of Asian women ($N = 197$ and $N = 1,783$, both with 40%–50% Asian participants), one included Hispanic women (Palnati et al., 2021), and one included White women (Huvinen et al., 2018).

The studies with fewer promising effects (Amason et al., 2016; Berry et al., 2016; Cheung et al., 2019) had some noteworthy similarities. First, each study was a pilot or feasibility study; one was a quasi-experimental design of low quality. The interventions were less individualized and were provided in a group setting (Berry et al., 2013) via adaptive Short Message Service (SMS) with an algorithm based on daily steps from a wearable device (Cheung et al., 2019) or through two 30-minute education sessions (Amason et al., 2016). These interventions consisted of a single session during pregnancy, although the number of sessions varied in the postpartum period. In addition, in all three studies, participants were of diverse race/ethnicity. In two of these studies, there was a dominant racial/ethnic group, including African American women (60%; Berry et al., 2016) and South Asian women

(34/60; Cheung et al., 2019). However, researchers in none of the three studies specified culturally tailored interventions. Poor retention rates (45%–51%) were reported for two of the studies with multiple sessions (Berry et al., 2016; Cheung et al., 2019). Amason et al. (2016) provided only two intervention sessions with a greater retention rate (92%).

Discussion

Lifestyle interventions to decrease the risk of T2D in women with or at risk for GDM can improve health outcomes. Significant effects on outcomes related to T2D prevention were reported in four of the seven studies included in our review (e.g., glucose regulation and weight-related outcomes; Ferrara et al., 2011, 2016; Huvinen et al., 2018; Palnati et al., 2021). However, in three pilot or feasibility studies in our review, researchers reported no effect on these outcomes (Amason et al., 2016; Berry et al., 2016; Cheung et al., 2019). In addition, in five of the seven studies, participants significantly improved their healthy lifestyle behaviors (Berry et al., 2016; Ferrara et al., 2011, 2016; Huvinen et al., 2018; Palnati et al., 2021), and an association between increased physical activity and improved weight outcomes was reported (Palnati et al., 2021). Thus, providing lifestyle interventions at both stages of maternal care may improve weight, glucose regulation, and healthy behaviors.

There is considerably less research on lifestyle interventions during pregnancy and the postpartum period for women with GDM compared to research on lifestyle interventions during either pregnancy (Brown et al., 2017; Gilbert et al., 2019) or the postpartum period (Goveia et al., 2018; Guo et al., 2016). Although numerous studies have been conducted for women after GDM to prevent diabetes, many interventions were not delivered in the early postpartum period, which is critical for T2D prevention (Hedeager Momsen et al., 2021). In addition, implementing a DPP tailored for women with prior GDM has only reached a small proportion of the general population (Lim, 2021). More high-quality, adequately powered studies are warranted to understand the optimal dosages and characteristics of lifestyle interventions across the maternal care spectrum for women with GDM and to improve implementation of DPP for this population before and after birth.

Key characteristics of successful interventions

Goal setting to promote lifestyle changes was noted as a common theme in successful studies in our review. Goal setting is a frequently used behavioral intervention strategy in behavioral health research (Michie et al., 2018). An effective goal-setting strategy must attend to participants' abilities and commitments to achieve the goals and provide helpful feedback and adequate situational resources (Locke & Latham, 2019; Swann et al., 2021). It is possible that by differentiating the weight management goals, physical activity goals, and dietary goals during pregnancy and the postpartum period, women in the more successful interventions (Ferrara et al., 2011, 2016; Huvinen et al., 2018) maintained their commitment to the goals and received ongoing feedback. On the contrary, even though one of the less successful studies used adaptive SMS to set up individualized goals for physical activity, goal setting in this study may not have been as effective because of a lack of feedback and/or commitment to the goals (Cheung et al., 2019).

In the more successful interventions, individualized care was provided in the intervention group via an in-person visit or a combination of delivery modes (e.g., telephone and/or print, with or without an in-person visit). Individualized care addresses the personal traits of the individuals involved in a study, such as their varied goals, preferences, needs, and resources (Beck et al., 2010). Individualized care is essential because each participant can have different goals or be in different stages of behavioral change (Beck et al., 2010). In addition, individualized care may also facilitate better retention in intervention programs because participants may have better engagement and greater satisfaction with the program. In contrast, other delivery methods that are difficult to individualize (e.g., group-based delivery methods or SMS) were used more often in less successful lifestyle intervention studies in our review. In other systematic reviews (Guo et al., 2016; Jones et al., 2017), in-person or telephone-delivered individual sessions were reported as more effective in weight management and diabetes prevention than other methods (e.g., Web site only or educational sessions only).

In three out of four successful studies in our review, intervention programs were delivered in an integrated health care system (Ferrara et al., 2011, 2016; Huvinen et al., 2018). KPNC is one of the largest integrated managed care consortiums in the United States, serving more than 12 million members (Kaiser Permanente, 2021), and was the clinical site for two successful U.S.-based intervention programs in our review. KPNC provides continuous care to pregnant women with or without GDM from pregnancy to the postpartum period. This care system allows for a smooth transition in care, which may contribute to the success of both studies at 1 year postpartum, including good attendance and excellent retention rates. Similarly, Finland has a universal health care system with municipal health centers providing maternal and child care, primary care, and even preventive care in one location (Teperi et al., 2009). On the contrary, in most other health care systems in the United States, women's pregnancies are managed by obstetricians, midwives, or women's health nurse practitioners until the postpartum visit at approximately 6 weeks after birth (American College of Obstetricians and Gynecologists, 2018). There is no infrastructure for women's continued care, including prevention interventions, during the first year after birth. However, the implementation of electronic medical records has the potential to support a more integrated care model in the United States (Janett & Yeracaris, 2020). The relatively recent merging of community hospitals with large medical centers may also improve access to integrated women's health care during pregnancy and the first year after childbirth (Fulton, 2017).

Areas for improvement

Successful recruitment and retention of participants during and after pregnancy are essential for the effectiveness of lifestyle interventions to prevent T2D among women with GDM (Dasgupta et al., 2018). There were more intervention sessions provided during pregnancy in the more successful interventions included in our review (Ferrara et al., 2011, 2016; Huvinen et al., 2018; Palnati et al., 2021) compared to the three less successful interventions (Amason et al., 2016; Berry et al., 2016; Cheung et al., 2019). This contrast indicates that more intervention sessions during pregnancy may improve women's engagement in lifestyle interventions. Providing interventions starting in pregnancy may improve recruitment and

engagement (Dasgupta et al., 2018) and capitalize on the "teachable moment" during pregnancy (Phelan, 2010). In addition, the postpartum period is an incredibly challenging time in which to maintain healthy lifestyle behaviors (Makama et al., 2021). Because most attrition happened in the early postpartum period (6-week or 6-month postpartum follow-up visits) in the studies included in our review, maintaining healthy lifestyles in the early postpartum period may be most challenging, especially right after birth or around the time women return to work (Berry et al., 2016). Finally, researchers of future intervention studies should carefully design intervention delivery (e.g., the frequency and modes of delivery) to balance intervention effectiveness and successful retention of participants. A convenient and flexible intervention schedule is vital for participant retention; however, it should not compromise the effectiveness of the intervention (Palnati et al., 2021).

Providing more culturally sensitive care also appears warranted. Immigrant women in the United States have a greater prevalence of GDM than U.S.-born women (Deputy et al., 2018), but addressing unique immigration-related stress and needs was rarely reported. Furthermore, Asian women have the greatest GDM prevalence in the United States (Deputy et al., 2018) and worldwide (Guariguata et al., 2014). Interestingly, Asian women are also more susceptible to GDM (Hedderson et al., 2012) and T2D (Hsu et al., 2015) at lower BMIs, likely because of different body composition and a tendency to develop visceral adiposity. Even though most of the interventions in our review were individualized, only one intervention was designed to be culturally sensitive (Burkart et al., 2020; Palnati et al., 2021) for Hispanic women. Greater racial and ethnic diversity is needed in future research to understand unique challenges and solutions pertaining to T2D risk.

Limitations

Our review has several limitations. First, only a small number of lifestyle interventions during pregnancy and the postpartum period for women with GDM were identified, and most of the studies had fair methodologic quality. Second, our searches were limited to English-language articles, and we likely missed some studies reported in other languages. The studies in our review were conducted in developed countries only. Finally, only one of the seven studies was culturally tailored to an ethnic group, indicating a need for more research regarding racial and ethnic minority groups (e.g., Asian, Native American, Hispanic, or Black women).

Conclusion

Lifestyle interventions related to GDM provided during pregnancy and the postpartum period to prevent T2D have the potential to reduce women's risk for T2D. Health care providers at all stages of maternity care need to emphasize the health risk of T2D in women with histories of GDM and incorporate healthy lifestyle education into their care of women. Future researchers can address the limitations of current lifestyle intervention research by improving participant recruitment and retention, increasing the diversity of participants, and evaluating personalized and culturally sensitive interventions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

REFERENCES

Amason JS, Lee S-Y, Aduddell K, Hewell SW, & Van Brackle L (2016). Pilot feasibility study of an educational intervention in women with gestational diabetes. Journal of Obstetric. Gynecologic, & Neonatal Nursing, 45(4), 515–527. 10.1016/j.jogn.2016.04.003

American College of Obstetricians and Gynecologists. (2018). ACOG practice bulletin no. 190: Gestational diabetes mellitus. Obstetrics & Gynecology, 131(2), e49–e64. 10.1097/aog.0000000000002501 [PubMed: 29370047]

Aroda VR, Christophi CA, Edelstein SL, Zhang P, Zhuo X, Herman WH, … Diabetes Prevention Program Research Group. (2015). The effect of lifestyle intervention and metformin on preventing or delaying diabetes among women with and without gestational diabetes: The Diabetes Prevention Program Outcomes study 10-year follow-up. Journal of Clinical Endocrinology & Metabolism, 100(4), 1646–1653. 10.1210/jc.2014-3761 [PubMed: 25706240]

Beck C, McSweeney JC, Richards KC, Roberson PK, Tsai PF, & Souder E (2010). Challenges in tailored intervention research. Nursing Outlook, 58(2), 104–110. 10.1016/j.outlook.2009.10.004 [PubMed: 20362779]

Berry DC, Hall E, Neal MN, Adatorwovor R, Schwartz TA, & Stuebe A (2016). Results of the optimizing outcomes in women with gestational diabetes mellitus and their infants. a cluster randomized, controlled pilot study: Lessons learned. Journal of the National Black Nurses Association. 27(2). 1–10.

Berry DC, Neal M, Hall EG, Schwartz TA, Verbiest S, Bonuck K, … Stuebe AM (2013). Rationale, design, and methodology for the optimizing outcomes in women with gestational diabetes mellitus and their infants study. BMC Pregnancy and Childbirth, 13, Article 184. 10.1186/1471-2393-13-184 [PubMed: 24112417]

Bgeginski R, Ribeiro PAB, Mottola ME, & Ramos JGL (2017). Effects of weekly supervised exercise or physical activity counseling on fasting blood glucose in women diagnosed with gestational diabetes mellitus: A systematic review and meta-analysis of randomized trials. Journal of Diabetes, 9(11), 1023–1032. 10.1111/1753-0407.12519 [PubMed: 28032459]

Brown J, Alwan NA, West J, Brown S, McKinlay CJD, Farrar D, & Crowther CA (2017). Lifestyle interventions for the treatment of women with gestational diabetes. Cochrane Database of Systematic Reviews. 10.1002/14651858.CD011970.pub2

Buelo AK, Kirk A, Lindsay RS, & Jepson RG (2019). Exploring the effectiveness of physical activity interventions in women with previous gestational diabetes: A systematic review of quantitative and qualitative studies. Preventive Medicine Reports. 14, 100877. 10.1016/j.pmedr.2019.100877 [PubMed: 31110933]

Burkart S, Marcus BH, Pekow P, Rosal MC, Manson JE, Braun B, & Chasan-Taber L (2020). The impact of a randomized controlled trial of a lifestyle intervention on postpartum physical activity among at-risk Hispanic women: Estudio PARTO PLOS ONE, 15(7), Article e0236408. 10.1371/journal.pone.0236408 [PubMed: 32706812]

Chasan-Taber L, Marcus BH, Rosal MC, Tucker KL, Hartman SJ, Pekow P, … Markenson G (2014). Estudio Parto: Postpartum diabetes prevention program for Hispanic women with abnormal glucose tolerance in pregnancy: A randomised controlled trial—Study protocol. BMC Pregnancy and Childbirth. 14, Article 100. 10.1186/1471-2393-14-100 [PubMed: 24606590]

Cheung NW, Blumenthal C, Smith BJ, Hogan R, Thiagalingam A, Redfern J, … Chow CK (2019). A pilot randomised controlled trial of a text messaging intervention with customisation using linked data from wireless wearable activity monitors to improve risk factors following gestational diabetes. Nutrients, 11(3), Article 590. 10.3390/nu11030590

Dall TM, Yang W, Halder P, Pang B, Massoudi M, Wintfeld N, … Hogan PF (2014). The economic burden of elevated blood glucose levels in 2012: Diagnosed and undiagnosed diabetes, gestational

diabetes mellitus. and prediabetes. Diabetes Care, 37(12), 3172–3179. 10.2337/dc14-1036 [PubMed: 25414388]

Dasgupta K, Terkildsen Maindal H, Kragelund Nielsen K, & O'Reilly S (2018). Achieving penetration and participation in diabetes after pregnancy prevention interventions following gestational diabetes: A health promotion challenge. Diabetes Research and Clinical Practice. 145. 200–213. 10.1016/j.diabres.2018.04.016 [PubMed: 29684615]

Deputy NP, Kim SY, Conrey EJ, & Bullard KM (2018). Prevalence and changes in preexisting diabetes and gestational diabetes among women who had a live birth—United States. 2012–2016. MMWR Morbidity & Mortality Weekly Report. 67(43). 1201–1207. 10.15585/mmwr.mm6743a2

Farrar D, Simmonds M, Bryant M, Sheldon TA, Tuffnell D, Golder S, … Lawlor DA (2016). Hyperglycaemia and risk of adverse perinatal outcomes: Systematic review and meta-analysis. BMJ, 354. Article i4694. 10.1136/bmj.i4694 [PubMed: 27624087]

Ferrara A, Hedderson MM, Albright CL, Brown SD, Ehrlich SF, Caan BJ, … Quesenberry CP Jr. (2014). A pragmatic cluster randomized clinical trial of diabetes prevention strategies for women with gestational diabetes: Design and rationale of the Gestational Diabetes' Effects on Moms (GEM) study. BMC Pregnancy and Childbirth. 14. Article 21. 10.1186/1471-2393-14-21 [PubMed: 24423410]

Ferrara A, Hedderson MM, Albright CL, Ehrlich SE, Quesenberry CP Jr., Peng T, … Crites Y (2011). A pregnancy and postpartum lifestyle intervention in women with gestational diabetes mellitus reduces diabetes risk factors: A feasibility randomized control trial. Diabetes Care, 34(7), 1519–1525. 10.2337/dc10-2221 [PubMed: 21540430]

Ferrara A, Hedderson MM, Brown SD, Albright CL, Ehrlich SE, Tsai AL, … Quesenberry CP Jr. (2016). The comparative effectiveness of diabetes prevention strategies to reduce postpartum weight retention in women with gestational diabetes mellitus: The Gestational Diabetes' Effects on Moms (GEM) cluster randomized controlled trial. Diabetes Care, 39(1), 65–74. 10.2337/dc15-1254 [PubMed: 26657945]

Fulton BD (2017). Health care market concentration trends in the United States: Evidence and policy responses. Health Affairs. 36(9). 1530–1538. 10.1377/hlthaff.2017.0556 [PubMed: 28874478]

Gilbert L, Gross J, Lanzi S, Quansah DY, Puder J, & Horsch A (2019). How diet, physical activity and psychosocial well-being interact in women with gestational diabetes mellitus: an integrative review. BMC Pregnancy Childbirth, 19(1), 60. 10.1186/s12884-019-2185-y [PubMed: 30732571]

Goveia P, Cañon-Montañez W, Santos DP, Lopes GW, Ma RCW, Duncan BB, … Schmidt M. l. (2018). Lifestyle intervention for the prevention of diabetes in women with previous gestational diabetes mellitus: A systematic review and meta-analysis. Frontiers in Endocrinology, 9, Article 583. 10.3389/fendo.2018.00583 [PubMed: 30344509]

Grossetta Nardini HK, & Wang L (2020). The Yale MeSH analyzer. https://mesh.med.yale.edu/

Guariguata L, Linnenkamp IJ, Beagley J, Whiting DR, & Cho NH (2014). Global estimates of the prevalence of hyperglycaemia in pregnancy. Diabetes Research and Clinical Practice, 103(2), 176–185. 10.1016/J.diabres.2013.11.003 [PubMed: 24300020]

Guo J, Chen JL, Whittemore R, & Whitaker E (2016). Postpartum lifestyle interventions to prevent type 2 diabetes among women with history of gestational diabetes: A systematic review of randomized clinical trials. Journal of Women's Health. 25(1) 38–49. 10.1089/jwh.2015.5262

Hedderson M, Ehrlich S, Sridhar S, Darbinian J, Moore S & Ferrara A (2012). Racial/ethnic disparities in the prevalence of gestational diabetes mellitus by BMI. Diabetes Care. 35(7). 1492–1498. 10.2337/dc11-2267 [PubMed: 22619080]

Hedeager Momsen AM, Høtoft D, Ørtenblad L, Lauszus Friis, Krogh F, R. H. A., Lynggaard V … Vinther Nielsen C (2021). Diabetes prevention interventions for women after gestational diabetes mellitus: An overview of reviews. Endocrinology, Diabetes and Metabolism, 4(3), Article e00230. 10.1002/edm2.230.

Hsu WC, Araneta MRG, Kanaya AM, Chiang JL, & Fuji-moto W (2015). BMI cut points to identify at-risk Asian Americans for type 2 diabetes screening. Diabetes Care, 38(1), 150–158. 10.2337/dc14-2391 [PubMed: 25538311]

Huvinen E, Koivusalo SB, Meinila J, Valkama A, Tiitinen A, Rono K, … Eriksson JG (2018). Effects of a lifestyle intervention during pregnancy and first postpartum year: Findings from the RADIEL

study Journal of Clinical Endocrinology & Metabolism, 103(4), 1669–1677. 10.1210/jc.2017-2477 [PubMed: 29409025]

Janett RS, & Yeracaris PP (2020). Electronic medical records in the American health system: Challenges and lessons learned. Ciencia & Saude Coletiva, 25(4), 1293–1304. 10.1590/1413-81232020254.28922019 [PubMed: 32267432]

Jones EJ, Fraley HE, & Mazzawi J (2017). Appreciating recent motherhood and culture: A systematic review of multimodal postpartum lifestyle interventions to reduce diabetes risk in women with prior gestational diabetes. Maternal and Child Health Journal, 21(1), 45–57 10.1007/s10995-016-2092-z [PubMed: 27435732]

Kaiser Permanente. (2021). Fast facts https://about.kaiserpermanente.org/who-we-are/fast-facts

LaManna JB, & Quelly SB (2020). After gestational diabetes: An overlooked care transition in primary care. Journal for Nurse Practitioners, 16(5), 319–323. 10.1016/j.nurpra.2020.01.016

Lit N, Yang Y, cui D, U C, Ma RCW, Li J, & Yang X (2020). Effects of lifestyle intervention on long-term risk of diabetes in women with prior gestational diabetes: A systematic review and meta-analysis of randomized controlled trials. Obesity Reviews, 22(1), Article e13122. 10.1111/obr.13122 [PubMed: 33316148]

Li Z, Cheng Y, Wang D, Chen H, Chen H, Ming WK, & Wang Z (2020). Incidence rate of type 2 diabetes mellitus after gestational diabetes mellitus: A systematic review and meta-analysis of 170,139 women. Journal of Diabetes Research, 2020. Article 3076463. 10.1155/2020/3076463 [PubMed: 32405502]

Lim S (2021). Preventing type 2 diabetes in women with previous gestational diabetes: Reviewing the implementation gaps for health behavior change programs. Seminars in Reproductive Medicine. 38(6). 377–383. 10.1055/s-0040-1722315

Locke EA, & Latham GP (2019). The development of goal setting theory: A half century retrospective. Motivation Science, 5(2)93–105. 10.1037/mot0000127

Makama M, Awoke MA, Skouteris H, Moran LJ, & Lim S (2021). Barriers and facilitators to a healthy lifestyle in postpartum women: A systematic review of qualitative and quantitative studies in postpartum women and healthcare providers. Obesity Reviews. 22(4) Article e13167. 10.1111/obr.13167 [PubMed: 33403746]

Michie S, west R, Sheals K, & Godinho CA (2018). Evaluating the effectiveness of behavior change techniques in health-related behavior: A scoping review of methods used. Translational Behavioral Medicine, 8(2), 212–224. 10.1093/tbm/ibx019 [PubMed: 29381786]

Moher D, Liberati A, Tetzlaff J, Altman DG, & the PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLOS Medicine, 6(7), Article e1000097. 10.1371/journal.pmed.1000097 [PubMed: 19621072]

National Heart, Lung, and Blood Institute. (2020). Study quality assessment tools. https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools

Nielsen KK, Kapur A, Damm P, de Courten M, & Bygbjerg l. C. (2014). From screening to postpartum follow-up – The determinants and barriers for gestational diabetes mellitus (GDM) services, a systematic review BMC Pregnancy and Childbirth, 14. Article 41. 10.1186/1471-2393-14-41 [PubMed: 24450389]

Palnati M, Marcus BH, Pekow P, Rosal MC, Manson JE, & Chasan-Taber L (2021). The impact of a lifestyle intervention on postpartum weight retention among at-risk Hispanic women. American Journal of Preventive Medicine, 61(1), 44–54. 10.1016/j.amepre.2021.02.005 [PubMed: 33994252]

Phelan S (2010). Pregnancy: A "teachable moment" for weight control and obesity prevention. American Journal of Obstetrics & Gynecology, 202(2), 135.E1–135.E8. 10.1016/j.ajog.2009.06.008 [PubMed: 19683692]

Song C, Lyu Y, Li C, Liu P, Li J, Ma RC, & Yang X (2018). Long-term risk of diabetes in women at varying durations after gestational diabetes: A systematic review and meta-analysis with more than 2 million women. Obesity Reviews. 19(3). 421–429. 10.1111/obr.12645 [PubMed: 29266655]

Sterne JAC, Savovi J, Page MJ, Elbers RG, Blencowe NS, Boutron I, … Higgins JPT (2019). RoB 2: A revised tool for assessing risk of bias in randomised trials. BMJ. 366. Article I4898. 10.1136/bmj.I4898

Swann C, Rosenbaum S, Lawrence A, Vella SA, McEwan D, & Ekkekakis P (2021). Updating goal-setting theory in physical activity promotion: A critical conceptual review. Health Psychology Review.15(1) 34–50. 10.1080/17437199.2019.1706616 [PubMed: 31900043]

Teperi J, Porter ME, Vuorenkoski L, & Baron JE (2009). The Finnish health care system: A value-based perspective. https://web.archive.org/web/20160809151216/https://www.sitra.fi/julkaisut/raportti82.pdf

Van Ryswyk E, Middleton P, Shute E, Hague W, & Crowther C (2015). Women's views and knowledge regarding healthcare seeking for gestational diabetes in the postpartum period: A systematic review of qualitative/survey studies. Diabetes Research and Clinical Practice, 110(2), 109–122. 10.1016/j.diabres.2015.09.010 [PubMed: 26421361]

Vounzoulaki E, Khunti K, Abner SC, Tan BK, Davies MJ, & Gillies CL (2020). Progression to type 2 diabetes in women with a known history of gestational diabetes: Systematic review and meta-analysis. BMJ. 369. Article m1361. 10.1136/bmj.m1361 [PubMed: 32404325]

Wilkinson SA, Lim SS, Upham S, Pennington A, O'Reilly SL, Asproloupos D, … Dunbar JA (2014). Who's responsible for the care of women during and after a pregnancy affected by gestational diabetes? Medical Journal of Australia. 201(3 Supp), S78–S81. 10.5694/mja14.00251 [PubMed: 25047889]

Yamamoto JM, Kellen JE, Balsells M, García-Patterson A, Hadar E, Solà l., … Corcoy R (2018). Gestational diabetes mellitus and diet: A systematic review and meta-analysis of randomized controlled trials examining the impact of modified dietary interventions on maternal glucose control and neonatal birth weight. Diabetes Care, 41(7), 1346–1361. 10.2337/dc18-0102 [PubMed: 29934478]
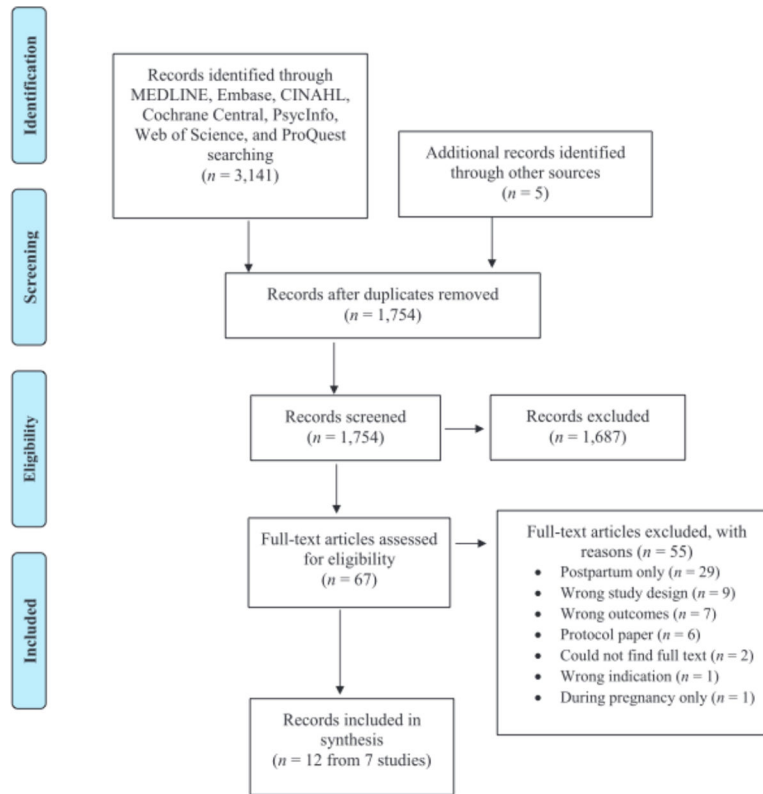
Figure 1.
Search strategy for the identification of publications included in this systematic review.

Table 1:

Effect on Outcomes by Study

Outcomes	With Effect[a]	Without Effect[b]
Glucose regulation	Huvinen et al. (2018): RCT	Berry et al. (2016): feasibility RCT Cheung et al. (2019): pilot RCT Ferrara et al. (2016): pragmatic RCT
Weight change	Ferrara et al. (2011): feasibility RCT Ferrara et al. (2016): pragmatic RCT Palnati et al. (2021): RCT	Berry et al. (2016): feasibility RCT Cheung et al. (2019): pilot RCT Huvinen et al. (2018): RCT
Physical activity	Berry et al. (2016): feasibility RCT Burkart et al. (2020): RCT Ferrara et al. (2016): pragmatic RCT	Amason et al. (2016): pilot controlled study Cheung et al. (2019): pilot RCT Ferrara et al. (2011): feasibility RCT Huvinen et al. (2018): RCT
Diet	Ferrara et al. (2011): feasibility RCT Huvinen et al. (2018): RCT	Amason et al. (2016): pilot controlled study Berry et al. (2016): feasibility RCT Cheung et al. (2019): pilot RCT Ferrara et al. (2016): pragmatic RCT
Knowledge	Amason et al. (2016): pilot controlled study	

Note. RCT = randomized controlled trial.

[a]Statistically significant effect ($p < .05$) on any types of outcomes.

[b]No statistically significant effect ($p \geq .05$) on any types of outcomes.