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Implementing weight management during and after pregnancy to reduce diabetes and CVD risk in maternal and child populations

Sharleen L. O'Reilly[1,2]*, Fionnuala M. McAuliffe[2], Aisling A. Geraghty[1,2], Christy Burden[3] and Anna Davies[3]

[1]*School of Agriculture and Food Science, University College Dublin College of Health Sciences, Dublin, Ireland*
[2]*UCD Perinatal Research Centre, National Maternity Hospital, University College Dublin School of Medicine, Dublin 2, Ireland*
[3]*Academic Women's Health Unit, Translational Health Sciences, Bristol Medical School, University of Bristol, Bristol, UK*

Maintaining a healthy weight during pregnancy is critical for both women's and children's health. Excessive gestational weight gain (GWG) can lead to complications such as gestational diabetes, hypertension and caesarean delivery. Insufficient GWG can cause fetal growth restriction and increase infant mortality risk. Additionally, postpartum weight retention raises risk of obesity, type 2 diabetes and other chronic diseases for both mother and child. This review seeks to identify current obstacles in weight management research during and after pregnancy and explore evidence-based strategies to overcome them. Pregnancy offers a window of opportunity for health behaviour changes as women are more receptive to education and have regular contact with health services. Staying within Institute of Medicine's recommended GWG ranges is associated with better maternal and fetal outcomes. Systematic review evidence supports structured diet and physical activity pregnancy interventions, leading to reduced GWG and fewer complications. Health economic evaluation indicates significant returns from implementation, surpassing investment costs due to decreased perinatal morbidity and adverse events. However, the most effective way to implement interventions within routine antenatal care remains unclear. Challenges increase in the postpartum period due to competing demands on women physically, mentally and socially, hindering intervention reach and retention. Flexible, technology-supported interventions are needed, requiring frameworks such as penetration-implementation-participation-effectiveness and template-for-intervention-description-and-replication for successful implementation. Greater research efforts are necessary to inform practice and investigate fidelity aspects through pragmatic implementation trials during the pregnancy and postpartum periods. Understanding the best ways to deliver interventions will empower women to maintain a healthy weight during their reproductive years.

Maternal obesity: Gestational diabetes: Health behaviour: Implementation science

Abbreviations: BCT, behaviour change technique; EBP, evidence-based practice; EPIS, exploration, preparation, implementation, sustainment; GDM, gestational diabetes; GWG, gestational weight gain; MRC, UK Medical Research Council; NPT, normalisation process theory; PIPE, penetration-implementation-participation-effectiveness; T2D, type 2 diabetes..

***Corresponding author:** Sharleen L. O'Reilly, email sharleen.oreilly@ucd.ie

Introduction

Global obesity rates are climbing, and women are no exception. Obesity is defined as 'abnormal or excessive fat accumulation that presents a risk to health', and BMI is the most common method used to measure prevalence rates[1]. At a population level, the female overweight and obesity rates are high for Ireland (24·5 % overweight/26 % obesity) and the United Kingdom (31 % overweight/28 % obesity)[1], making obesity-related malnutrition a substantial issue being faced by over a quarter of adult females in these countries[1]. Low- and middle-income countries experience a double malnutrition burden with undernutrition remaining prevalent in rural communities but overnutrition forms an increasing challenge for urban settings[2]. Overweight- and obesity-related disease accounts for 4 million deaths annually[3].

During pregnancy, women are expected to gain weight. The weight gained for a woman with a normal BMI is 13·6 kg, of which 25 % is the baby, 26 % blood and body fluids, 23 % maternal stores of fat, protein and other nutrients, 7 % breast tissue, 7 % uterus, 7 % amniotic fluid and 5 % placenta[4]. Weight gained between conception and birth is termed gestational weight gain (GWG) and recommendations by the former US Institute of Medicine (now National Academy of Medicine) outline GWG based on pre-pregnancy BMI categories[5]. Weight gained beyond these ranges is termed excessive GWG and linked with poorer health outcomes[6]. Following birth, the focus shifts to a woman returning to their pre-pregnancy weight and rapid weight loss is discouraged. Intrapartum weight retention refers to the weight retained and gained between pregnancies and is a key long-term negative maternal health indicator. Women have sustained engagement with their healthcare system during their reproductive years and these encounters have the potential to improve longer-term health if they can be optimised with preconception, antenatal and postpartum weight management being connected and using the best available evidence to inform practice.

This review firstly aims to explore the impact of entering pregnancy with overweight/obesity, excessive weight gain and intrapartum weight retention on health outcomes, associated risk and cost. Secondly, it will explore implementation science approaches to bridging the translation of research into practice and related behaviour change frameworks used in this implementation. Finally, the review will look at interventions to support healthy weight management across the antenatal and postpartum periods.

Maternal obesity: prevalence, cost, associated risk

Obesity in pregnancy is a significant contributor to maternal and perinatal morbidity and mortality with a rising global prevalence among reproductive-aged women. The global prevalence of obesity has significantly increased in the past decades, described as a 'global epidemic',[7] with the number of people with overweight and obesity tripling between 1975 and 2016[8]. Less than half of pregnant women in the UK have a BMI in the normal range in the UK and 47 % of pregnant women have GWG greater than Institute of Medicine recommendations[9]. Moreover, internationally over half of all reproductive-aged women are entering pregnancy overweight and half exceed recommended GWG[10].

Gestational diabetes (GDM), new onset of diabetes in pregnant women without a prior history, is one of the most common complications associated with obesity in pregnancy[11]. It is defined as high blood sugar levels during pregnancy and is an increasing health problem for both mothers and babies, affecting up to 18 % of pregnancies worldwide. European GDM prevalence varies – north 8·9 %, east 31·5 %, south 12·3 % and west 10·7 %[12]. High BMI (>25 kg/m^2) is the most important modifiable risk factor for GDM, with 6·8-fold higher risk for BMIs >30 kg/m^2 compared to normal BMIs (18·5–24·9 kg/m^2)[12]. The effects of GWG, GDM, hyperglycaemia and obesity on adverse pregnancy outcomes and on fetal and offspring development are significant. The risk of miscarriage and congenital anomalies has been shown to increase with hyperglycaemia during organogenesis. GDM, hyperglycaemia, obesity and GWG are associated with increased odds of pregnancies affected by neural tube defects (OR, 1·87), spina bifida (OR, 2·24), cardiovascular anomalies (OR, 1·30), septal anomalies (OR, 1·20), cleft palate (OR, 1·23), cleft lip and palate (OR, 1·20), anorectal atresia (OR, 1·48), hydrocephaly (OR, 1·68), limb reduction anomalies (OR, 1·34)[13] intellectual disability and poorer cognitive development[14]. GDM is also associated with a long-term tenfold increased maternal risk of type 2 diabetes (T2D)[15]. Strong evidence exists that health behaviour change can reduce the development of T2D in people at risk[16,17], but there are many demands on a new mother and weight gained during pregnancy is frequently not lost afterwards leading to increased risk of obesity, heart disease and diabetes[18,19]. This risk is not confined to just the woman, early fetal programming means that her offspring also have demonstrable increased risk – her children are eight times more likely to develop diabetes or pre-diabetes by early adulthood[20] with a 59 % increased risk of developing childhood obesity[21].

Women with GDM and those living with obesity demonstrate increased insulin resistance in pregnancy and this creates poorer metabolic health, which can even impact placental structure, maternal and cord inflammatory markers as well as endocrine and inflammatory gene expression[22]. This common footing between GDM and obesity results in women living with obesity being at increased risk of GDM, preeclampsia, gestational hypertension, fetal macrosomia, caesarean section and postpartum weight retention[23]. Furthermore, obesity and GWG in pregnancy increase the risk of complications during labour and birth[24]. Evidence has demonstrated that women with overweight (BMI>25 kg/m^2) were more likely to have a slower labour progression, potentially due to the inadequacy of uterine contractions,

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and fetal distress and ultimately therefore receiving interventions such as labour induction/augmentation or operative birth[25]. Women with obesity who undergo caesarean birth are additionally at increased risk for anaesthesia-related complications (epidural failure, aspiration under general anaesthesia and difficult endotracheal intubation) and post-operative wound infection[26]. Venous thromboembolism is a further serious risk in pregnant women with obesity. Evidence has demonstrated that up to 57 % of women in the UK who died from venous thromboembolism during pregnancy had BMIs in the obese category[27]. Fetal macrosomia is a neonatal complication associated with obesity in pregnancy[24] and GDM and itself increase the risk for operative delivery and maternal and infant morbidity. It is associated with maternal complications such as genital tract lacerations, and postpartum haemorrhage. Infants have an increased risk of shoulder dystocia, clavicular fractures, brachial plexus injuries and nerve palsies. Importantly, GDM is associated with a high risk of neonatal intensive care unit admission, due to further associated complications such as neonatal hypoglycaemia[28].

Maternal BMI influences maternal and neonatal morbidity, the number and duration of maternal and neonatal admissions and health service costs[29]. The most recent Mothers and Babies: reducing risk through audits and confidential enquiries across the UK (MBRRACE-UK) report identified maternal obesity as a significant factor in up to 30 % of maternal deaths in the UK and Ireland[27] and this rate is seen in other countries[30,31]. Rising obesity within the obstetric populations will mean that this factor will only continue to grow and impact parents, families and the wider society. The prevalence of stillbirth in the UK is above the European average, affecting almost 1 in 250–300 pregnancies after 28 weeks of pregnancy[32]. The MBRRACE report concluded that up to 60 % of antepartum stillbirths could have been prevented with improved antenatal care[27].

Even modest increases in maternal BMI are associated with increased risk of fetal death, stillbirth and neonatal, perinatal and infant death. For BMIs of 25 and 30 kg/m^2, the absolute risk per 10 000 pregnancies for fetal death are 82 and 102; for stillbirth 48 and 59 and for perinatal death 73 and 86[33]. For women who gain four or more BMI units between pregnancies, their risk is 55 % higher for stillbirth and 29 % higher for infant mortality[34]. We also know that stillbirth risk increases linearly with increased BMI gain and that weight loss prior to a subsequent pregnancy in women with overweight will decrease neonatal mortality[34]. The risk of late stillbirth is much greater when GDM is not diagnosed – 44 % increase in women at risk of GDM but not screened and women with raised fasting plasma glucose not diagnosed with GDM experienced a fourfold greater risk of late stillbirth than women with normal blood glucose[35]. The increased focus on detection and management was a key recommendation of the MBRRACE report to decrease stillbirths[27]. Eleven per cent of neonatal deaths

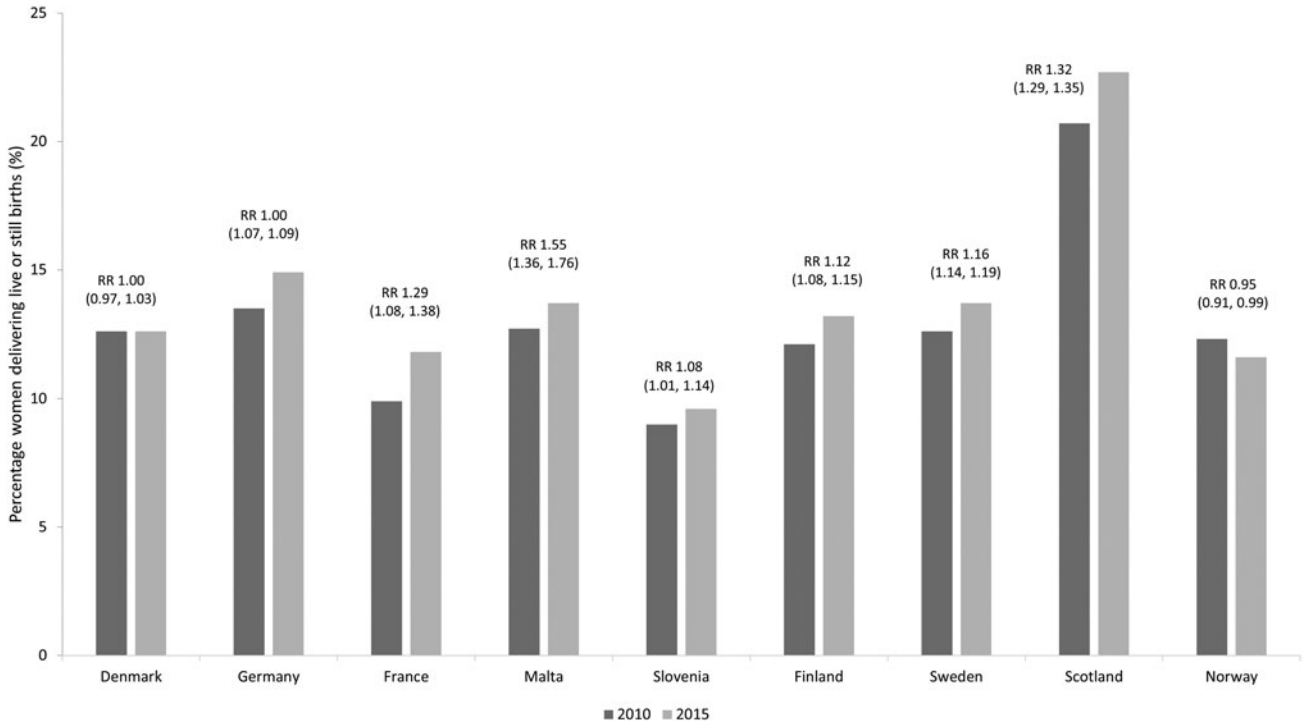

Fig. 1. Comparison of the percentages of women with a pre-pregnancy BMI ≥30 from 2010 and 2015 (risk ratios and 95 % CI). Pooled random-effects model estimate 1·15 (95 % CI 1·08, 1·22). Adapted from European Perinatal Health Report 2018[36].

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are attributed to maternal overweight and obesity (Fig. 1)[36].

Inappropriate GWG is a challenge that weighs heavily on this population but they are also the most nutritionally vulnerable. Suboptimal micronutrient (iron, vitamin D, folate, vitamin B6, magnesium, zinc, potassium and vitamin A) and macronutrient (fibre and carbohydrate) intakes alongside excessive sodium and dietary fat intakes are seen in these women[37]. Dietary quality is known to continue to be poor in this population postpartum[38] and yet it is known that higher dietary quality in pregnancy and lactation are associated with a healthier growth pattern in infants[39] and better weight maintenance[40]. Maternal nutrition and interventions to reduce maternal complications from suboptimal nutrition are priorities for the WHO[41] and the International Federation of Gynaecology and Obstetrics. The International Federation of Gynaecology and Obstetrics recently established a specific pregnancy non communicable disease (NCD) prevention committee which aims to tackle obesity and GDM as one of its cornerstone aims[10,11]. Pregnancy and infant first year of life are a window of opportunity to future health and the long-term effects of obesity in pregnancy needs consideration. Compared to normal-weight women, women with obesity were shown to retain more weight postpartum. More specifically, postpartum weight gain was most strongly associated with weight gain during the first trimester[42] and intrauterine exposure to maternal obesity can lead to adverse health outcomes in the offspring, including an increased incidence of metabolic syndrome and obesity in the child. Recent studies have shown that childhood obesity can be carried into adulthood, suggesting that fetal overnutrition can adversely affect the health of offspring throughout life[43]. Offspring of pregnant women with obesity have 35 % increased all-cause mortality and 29 % increased rates of hospital admission with CVD[44].

Maternal obesity, GWG and GDM place a substantial economic burden on healthcare systems. Pregnant women with overweight or obesity have a significantly greater number of maternal admissions, longer admissions and higher health service costs than women of normal weight[29]. Excess GWG will significantly increase risks and costs in pregnancy[45]. Moreover, infants born to mothers with high BMIs also utilise significantly more health service resources in the first year of life compared to infants born to mothers of healthy weight[46]; they are also at higher risk of developing childhood obesity[21]. Pregnant women with elevated BMI are at high risk of developing GDM, which also imposes additional costs independently of BMI[47]. The cost of managing GDM yielded an economic burden in the United States of $1·6 billion in 2017 with $5800 annual burden per case of GDM[48]. In Ireland, the costs of maternity care for women with a diagnosis of GDM are 34 % greater than in women without GDM[49]. Finally, women who develop GDM have a tenfold increased future risk of developing T2DM[15] and an increase in health-related costs is seen postpartum compared with normoglycaemic pregnancies (€680·50 in annual healthcare costs 2–5 years after the index pregnancy)[50]. Health services have seen an almost fourfold increase in GDM incidence caused by a widening of the diagnostic criteria, growing obesity rates and advancing maternal age[51]. In this GDM tsunami, health services are not resourced to manage such numbers and already extended services are further diluted. Currently, health systems around the world do not have sufficient resources to manage the numbers of women at risk of developing GDM to support them reducing their health behaviour-related risks.

Adverse outcomes in pregnancy for both woman and child are socially patterned with greater risk present in low socioeconomic and education, rural and ethnically diverse and minority populations[27]. Rates of obesity, T2DM and GDM are also higher in these populations[52–54] and intrinsically linked to the higher rates of adverse outcomes seen. Women from disadvantaged communities are currently not engaging or minimally engaging with health services to reduce their GWG and their risks of GDM, T2DM and obesity. Disadvantaged communities will typically not have access to support that fits with their needs owing to linguistic or cultural issues, competing interests of working life and raising a family and lack of financial resources to engage with provided services[55]. This systematic discrimination means that the most vulnerable are not able to engage with the care that will positively influence their health. While this will be for a range of reasons, unhealthy lifestyle behaviours promoting weight gain and access to universal screening for GDM is a part of this problem[27]. Similarly in the postpartum period, women are not engaging in diabetes screening[56,57] and/or risk reduction programmes[58,59], both of which will influence their reproductive health. Guidelines for improved health outcomes in both the woman and child are in place nationally and internationally for healthy weight gain, physical activity and eating in pregnancy, health weight management and lifestyle behaviours postpartum and healthy infant feeding practices. Yet the daily challenge that presents in maternity services and public health settings is how to implement these guidelines with fidelity using the few resources available within those settings.

Implementation science approaches: frameworks, hybrid designs and health behaviour change

A key issue in the development of effective interventions to support weight management during pregnancy and postpartum is the evidence to implementation ('know-do') gap. It has been estimated that it takes 17 years for evidence to be adopted into practice[60]. The growing field of implementation science aims to use evidence and theory-informed approaches to address this gap. The UK Medical Research Council (MRC) updated its framework for the development and evaluation of randomised controlled trials for complex interventions to improve health in 2019 and 2021[61,62]. Intervention complexity can impact implementation and achieving effect

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in different settings, due to challenges relating to: standardising intervention design and delivery, sensitivity to local context, the people involved (i.e. staff and patients), organisational context and development of outcome measures and evaluation[63]. Intervention complexity has been defined in a number of different ways, including the number of interacting components, groups or organisational levels targeted, variability of outcomes, the degree of tailoring or flexibility of the intervention and whether the intervention has a non-linear causal pathway[62,64]. There is increased interest in systems thinking and conceptual mapping approaches in healthcare research to understand real-world complexity[65], by focusing on 'people, processes, activities, settings and structures and the dynamic relationships between them'[66]. A key update within the new MRC framework is a shift towards addressing how interventions interact with their context, and how the intervention interacts with systems change, to identify the conditions needed to achieve intended change mechanisms, and to ensure effectiveness in 'real-world' settings[62].

The MRC framework specifies that interventions should be systematically developed and evaluated using evidence and theory. Four phases are outlined, which can be addressed iteratively and in any order: (i) development/identification of the intervention, (ii) exploration of feasibility and acceptability, (iii) evaluation, (iv) implementation. Each component should address a number of core elements, relating to contextual considerations, programme theory, stakeholder engagement, identification of key uncertainties, refinement of the intervention and economic considerations[62]. The authors highlight that early consideration of intervention implementation and investigation of it within each development and evaluation phase can increase potential for its future adoption across settings. The MRC approach aligns with effectiveness-implementation hybrid designs[67], where evaluation of implementation and effectiveness are undertaken alongside one another. There are three types of hybrid design approaches and the balance between implementation and effectiveness will vary for each type. Hybrid type 1 primarily tests the effects of an intervention while observing and gathering information on implementation. A type 2 hybrid design involves dual testing of the intervention effectiveness and either a secondary aim or co-primary aim of testing implementation strategies. A hybrid type 3 primarily tests the implementation strategy while observing and gathering information on clinical intervention effectiveness[67].

The MRC framework highlights that interventions should be systematically developed using the best available evidence and appropriate theory. Theoretical frameworks are commonly used in the development stage to develop behaviour change interventions. The behaviour change wheel is commonly used framework to ensure complete and cohesive coverage[68]. Central to the behaviour change wheel are three core behavioural determinants (capability, opportunity and motivation), which have been organised into the COM-B model of behaviour change[68]. Used in parallel with the COM-B model, the behaviour change technique (BCT) taxonomy is a consensus-informed transparent and systematic means to specify the content of interventions in terms of 93 distinct BCT[69]. This was derived from the behaviour change wheel development[68] and a taxonomy for physical activity and nutrition BCT[70]. The BCT taxonomy provides a common language to describe the key ingredients in behaviour change interventions, which enables greater replicability and fidelity of intervention implementation across settings/contexts, and facilitates systematic evidence syntheses that aim to identify the most effective BCT for a given behaviour and/or context.

Implementation theories provide a framework to drive implementation strategies and to explore how or why interventions are successfully or unsuccessfully implemented[71]. Current implementation theories have differing aims, including guiding the process of applying evidence in practice, exploring what influences implementation, and evaluating intervention implementation[71]. The exploration, preparation, implementation, sustainment (EPIS) framework[72], and normalisation process theory (NPT)[73] fall within the first and second categories, and support exploration of barriers and facilitators to implementation. The EPIS framework[72] was developed from the literature on implementation in the public sector and allied health services. It has four implementation phases that describe the process through which an evidence-based practice (EBP) is adopted: exploration (consideration of the health needs of patients/communities and identification of best EBP), preparation (identification of potential contextual barriers and facilitators to implementation), implementation (EBP is adopted), sustainment (context structures, processes and supports are ongoing so that the EBP is delivered to achieve intended impacts). Within the EPIS framework, common and unique factors hypothesised to have a strong influence on implementation of EBP are described, from within the outer system context, the inner organisational context and factors related to the innovation itself[72]. Outer and inner context, and innovation factors, may be more or less important in the different EPIS phases. A key component of the EPIS framework is the recognition of the interconnectedness and relationships between outer and inner contexts, which are called bridging factors. Systematic reviews show EPIS as a flexible and robust implementation framework suitable for use across low-, middle- and high-income countries[74]. NPT[73] is an explanatory model that provides a means to understand what influences implementation, and can be used alongside EPIS to understand some of the contextual- and innovation-related factors that influence it[75]. It was developed within a variety of healthcare systems and looks at individual and collective behaviour shown to be important in empirically studied implementation processes[75]. As an action theory, it describes the mechanisms of social action involved in implementing a new practice. There are four areas to NPT which are coherence (making sense of the new practice/s), cognitive participation (buy-in), collective action (resourcing) and reflexive monitoring (appraisal and feedback)[76]. A systematic review of NPT identified it as a useful theory

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in a wide range of interventions and that it had a particular benefit in evaluation and understanding implementation as a dynamic process[75].

Evaluation is critical to understanding implementation and there are several frameworks to inform how evaluation is undertaken. The most commonly used are reach, effectiveness, adoption, implementation, maintenance (RE-AIM)[77,78], template-for-intervention-description-and-replication checklist[79] and the penetration-implementation-participation-effectiveness (PIPE) framework[80]. RE-AIM was originally developed to consistently report implementation of innovations, however more recently it has been used to inform programme planning[78]. It proposes five steps to translate research into action, each of which can be evaluated to understand intervention impact or targeted with tools and strategies to achieve implementation: reach (number of people willing to participate in the intervention or programme), effectiveness (impact of intervention on key outcomes), adoption (willingness of agents (settings) willing to initiate a programme), implementation (fidelity of delivery an use of intervention strategies) and sustainment (extent to which it becomes part of routine practices and policy). Template-for-intervention-description-and-replication is the template for intervention description and replication, which has twelve items that form a checklist to improve reporting of interventions so they can be replicated and implemented[79]. The items are brief name, why, what (materials), what (procedure), who provided, how, where, when and how much, tailoring, modifications, how well (planned) and how well (actual)[79]. The template-for-intervention-description-and-replication checklist is commonly used in systematic review to deconstruct interventions for implementation strategy analyses and meta-analyses[81]. Similarly, the PIPE impact metric[80] provides a framework to assess the implementation of health improvement programmes. The four PIPE elements are: (1) penetration of the programme into the population of interest, (2) implementation of the proposed intervention/programme/services, (3) participation in the programme and (4) effectiveness in generating expected outcomes. PIPE can be used to evaluate implementation and provide feedback about where to focus changes to improve performance of a programme[82].

Interventions to reduce excessive gestational weight gain and intrapartum weight retention: what works and what needs consideration for implementation

There is a need to take a holistic view of the best time to intervene for reducing excessive GWG and intrapartum weight retention and the evidence is conflicting. On one hand, addressing maternal BMI was shown to be the only preventative strategy that reduces childhood obesity[21] and recent systematic review found no evidence that maternal dietary and/or health behaviour change intervention during pregnancy alone modifies early childhood obesity risk[83]. Interpregnancy weight gain is also associated with increased rates of subsequent large for gestational age infants and higher rates of subsequent GDM, further emphasising the importance of the interpregnancy and postpartum periods in weight management[10,84]. Conversely, there is a clear need to target and achieve engagement in women with the most risk when they are most motivated to manage their health risk during pregnancy. Health behaviour change interventions during this time show improved dietary patterns, exercise habits and GWG with improved pregnancy outcomes. Level 1 evidence clearly demonstrates that antenatal health behaviour change interventions are effective in reducing GWG, adverse maternal and neonatal birth outcomes and reduced subsequent development of T2D[85,86]. A recent systematic review and meta-analysis of 117 randomised clinical trials with over 34 000 pregnancies showed that antenatal diet and physical activity-based interventions were associated with less GWG[85]. They reduced GWG (−1·15 kg; 95 % CI −1·40, −0·91), GDM risk (OR, 0·79; 95 % CI 0·70, 0·89) and total adverse maternal outcomes (OR, 0·89; 95 % CI 0·84, 0·94) when compared to routine antenatal care[85]. Interventions that combined diet and physical activity and behaviour change had the greatest impact on GWG[85]. Rates of women exceeding GWG recommendations (based on IOM criteria) were significantly lower after exercise-only and combined interventions during pregnancy. A separate systematic review also showed that when behavioural therapy supported combined diet and physical activity interventions, GWG was significantly reduced (standardised mean difference −0·16 kg; 95 % CI −0·28, −0·04, four trials, $n = 2132$)[87].

From an implementation perspective, the evaluation of existing pregnancy health behaviour change interventions ($n = 117$) using PIPE and template-for-intervention-description-and-replication frameworks leads to some interesting findings. Only 14 % interventions provided sufficient data to calculate penetration and where available the level of population penetration was low[88]. Implementation was reported with moderate fidelity and participation was variable[88]. The effectiveness analysis showed −1·15 kg GWG (95 % CI −1·4, −0·91)[88]. Allied healthcare professionals were the most common and most effective delivery agents (−1·36 kg GWG)[89]. Structured diet health behaviour change delivered individually was the most effective format (−3·91 kg GWG) and having a moderate number of sessions was significant in reducing GWG (−4·91 kg)[89]. Further cost-effectiveness analysis of systematic review data showed that structured diet and physical activity intervention would see $4·75 Australian dollars returned for every dollar invested by health funders, with cost offsets from reduced perinatal morbidity and adverse events exceeding intervention costs[90]. For the postpartum period, the penetration remained low and participation variable. The implementation fidelity was low and effectiveness analysis showed −2·3 kg weight loss with intervention[81]. Healthcare professional delivery remained more effective (−3·22 kg) compared with −0·99 kg non-healthcare professional delivery[81]. Diet and physical activity combined was more effective than physical activity intervention alone but the intensity (duration or number of sessions)

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and setting (group or individual) did not affect weight loss[81]. The most effective BCT strategies for greater reductions in energy intake were problem solving, goal setting, feedback on behaviour, self-monitoring, credible source, behavioural substitution and reviewing goal outcomes[91].

While we have evidence for what works for the antenatal and postpartum periods separately, the challenge remains for bridging the gap between pregnancy and postpartum care. Women with GDM in particular report feeling like they have been dropped by the hospital system once they deliver their baby and are left to struggle on trying to manage their future chronic risk with the additional stressors of rearing a young family[55,92]. Women place a large amount of trust in the hospital and their staff to support them during pregnancy[93] but continuity of care is not sustained beyond the immediate postpartum period. Research suggested that interventions postpartum can be successful in management postpartum weight, however most interventions to date have been short in duration and had a relatively short follow-up period [94]. Systematic review shows that only five interventions have been conducted that cross the pregnancy to postpartum divide for GWG or postpartum weight management and that the postpartum contact was minimal[95]. All the identified interventions were also not integrated into routine care and as such, fail to shed any light on their implementation potential. The other aspect to this gap is that the interventions all focus on behaviour change in either the woman or the infant but not both, yet there are clear opportunities to leverage the impact of change in this instance by creating a more holistic approach to behaviour change at the family unit level. Research also indicates that the guidance available to inform translating the evidence into practice is lacking in terms of health service implementation or optimal programme delivery[88,96,97]. There is a clear need to use implementation science methods to inform the integration of effective lifestyle interventions into routine antenatal and postpartum care if we are to reduce the burdens of overweight and obesity and its impacts. In addition to understanding how to integrate and implement effective programmes, we need to have programmes that can be delivered with fidelity across multiple contexts in a scalable, sustainable way.

Digitally delivered health behaviour change interventions can successfully influence inequality by increasing availability and access for users. Smartphones have near ubiquitous coverage in all socioeconomic groups. For example, almost 90 % of people in the UK and Spain own a smartphone[98] and mothers aged 18–49 years spend over 21 h/week on their smartphones[99]. Apps can provide 'around the clock' high-quality information as well as tailored support at low cost[100]. Women with low socioeconomic status commonly use apps during pregnancy but not postpartum because of the lack of quality apps, with a postnatal app gap[101]. Maternal wellbeing and education level have also been identified as an enabler for engagement with mhealth-based health behaviour change interventions in pregnancy[102,103]. Higher mhealth engagement occurs when a health care professional (HCP) does the referral, a credible source co-designs the app with user-tailored content and the app usage starts during pregnancy[81,104–107]. Reviews of nutritional information on smartphone apps for pregnancy found that although the volume of apps was high, the overall quality was low, they did not consistently provide accurate nutritional information and only a few used BCT[105,108]. While there is evidence that mobile smart phone applications may have a role to play[109], the literature evaluating pregnancy or postpartum apps effectiveness and long-term engagement is sparse. Reviews indicate little to no literature exists on how to deliver digital health coaching programmes most effectively, and that digital tools to support women are 'of low quality, had minimal behaviour change potential, and were potentially unsafe, with minimal linkage to evidence-based information or partnership with health care'[110]. A qualitative systematic review identified digital health interventions were highly acceptable to pregnant women with obesity or GDM both in pregnancy and postpartum[111]. Smartphone technology holds the potential to provide more advanced methods of delivering personalised health behaviour change messages, while reaching a greater number of women for significantly lower costs than would be possible with traditional methods. Implementation research around app-based interventions that cover pregnancy and postpartum periods presents a major gap that has still to be addressed.

Longer-term engagement is required for pregnancy and postpartum interventions to understand impact, yet the average duration of interventions is 6 months[81,88]. The LIFE-Moms consortium lifestyle interventions in women with overweight or obesity (n = 1150; interventions included variable types of diet, physical activity and behaviour change; three were for pregnancy only and four continued postpartum) analysis showed lower postpartum weight retention at 12 months (2·2 ± 7·0 *v.* control 0·7 ± 6·2 kg, respectively; −1·6 kg difference (95 % CI −2·5, −0·7; P = 0·0003))[112]. The odds (OR = 1·68 (95 % CI 1·26, 2·24)) of women returning to their pre-pregnancy weight at 1-year postpartum were significantly increased but the intervention did not impact infant anthropometry and it is very difficult to extract meaningful implementation-relevant information from these different interventions[112]. However, lifestyle interventions in pregnant and postnatal women do demonstrate improved dietary patterns, exercise habits, and GWG with improved pregnancy outcomes[85,113,114]. The challenge remains that most are intensive, have low penetration or uptake rates, low adherence or participation rates, are not co-designed or implementation informed, require costly personnel and resources or lack long-term follow-up[86,88,96,97]. They also do not generate evidence to address the most significant evidence practice gap – how to implement evidence-based interventions into routine care. Although evidence shows that health behaviour change can reduce GWG and intrapartum weight management, there is a large research translation

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gap about achieving implementable interventions with adequate population penetration and participation. Evidence to support the capacity for implementation of antenatal health behaviour change interventions in maternity care settings remains limited[88].

Implementation-focused interventions

There are several ongoing studies that are seeking to move the implementation of interventions forward into more real-world settings and whom their primary results are due in 2024. The first study is called Face-it[115] and this is a effectiveness-implementation hybrid type 1 design. The intervention seeks to change health behaviours around physical activity, diet and breastfeeding in the first postpartum year for women with previous GDM and their families. Face-it is a health system-based intervention with three core components that will be undertaken in Denmark[116]. The central intervention component is additional visits from the public health nurse covering the health behaviour changes required and these visits will see the public health nurse work with the family unit, rather than just the mother. The second component is mhealth coaching delivered by a healthcare professional using an app. The mhealth coaching is offered to both the woman and her partner. The final component is a structured communication system that sends the public health nurse the woman's maternity discharge letter (normally only provided to general practitioner) and provides the ability to send reminders to either the public health nurse, health coaches or the woman through the secure platform. The intervention used the MRC complex intervention design[62] to underpin the study and seeks to recruit 460 women into the randomised controlled trial in a ratio of two intervention to one usual care participants. The primary outcome is reduction in BMI from baseline to 12 months postpartum and implementation data will be collected to explore fidelity and PIPE metrics in detail.

The second implementation study is Optimal Me[117], which is a hybrid type 3 design and will be conducted in Australia. The study seeks to primarily test whether the implementation strategy of the intervention's health coaching is better delivered via telephone or online videoconferencing. Women will be randomised to either arm and both will have a mhealth app that will provide health behaviour change and text message support. Extended implementation data will be collected using the RE-AIM framework[77] to ensure the study penetration, reach, feasibility, acceptability, adoption and fidelity can be evaluated. Optimal Me aims to recruit 300 women of childbearing age who are not pregnant but wish to conceive in the next 12 months. This selective criterion is normally very challenging to recruit as one in two pregnancies is unplanned but it can be achieved because the women will be recruited through a private health insurance company and women are required to upgrade their policy if they wish to include maternity care in the following year. The study has been designed to use an alternative pathway to usual maternity care and as a result will have a higher socioeconomic position population, which will need to be accounted for in the analysis.

The final study is Bump2Baby and Me[118], which is a hybrid type 2 design and will recruit women during pregnancy in four countries (Ireland, England, Spain and Australia). Bump2Baby and Me will provide mhealth coaching from a healthcare professional via a smartphone app that will also support self-monitoring of diet, physical activity and weight as well as a private social media community and a tailored information library. The intervention is designed to sit alongside usual care in each country and facilitates communication between the maternity service provider and the health coaches. The study is a randomised controlled trial that seeks to recruit 800 women (200 per country) in their first trimester of pregnancy at-risk of developing GDM to either usual care or usual care and the intervention. The intervention will provide health coaching and app access for the duration of the woman's pregnancy and the first postpartum year. It will expand the health coaching provided during the first postpartum year to include healthy infant feeding and active play alongside healthy family meals. The study is underpinned by the EPIS framework and will use NPT to achieve better understanding of the factors that influenced normalisation of the intervention in both the healthcare setting and in the women[119]. The primary outcome of the randomised controlled trial is maternal weight at 12 months. The RE-AIM evaluation framework will be used to explore implementation and fidelity aspects as secondary outcomes[119].

Conclusion

Addressing weight management in pregnancy and the postpartum period is a well-recognised health and healthcare issue. To effectively tackle this issue, we need to understand the prevalence and impact of excessive GWG and intrapartum weight retention and how it varies within countries and different population subgroups. Excessive GWG and intrapartum weight retention are linked to adverse short- and long-term health outcomes, including GDM, obesity and T2D. The management of weight requires more longer-term, flexibly delivered and family-focused approaches, which are commonly not included for a variety of reasons, but they are what is needed to support long-term weight management. All of this means that there is insufficient evidence available to implement health behaviour change interventions within everyday care and health service delivery.

Implementation science presents an opportunity to develop and deliver interventions that are suitable for use within healthcare services and settings. Ongoing research illustrates different implementation science approaches to achieving improved maternal health during the peripartum window and providing personalised support at the right time and place for each woman

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leveraging technology and digital tools to facilitate self-monitoring and behavioural interventions. In conclusion, by addressing implementation challenges and adopting evidence-based approaches, more effective weight management in pregnancy and the postpartum period will be possible and ultimately improve maternal and child health outcomes worldwide.

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Conflict of Interest

None.

Authorship

S. L. O'. R. proposed the original concept and developed the first draft of the manuscript. All other authors contributed to the final draft. All authors have been involved in revising the manuscript, have given final approval of the version to be published and agree to be accountable for all aspects of the work. All authors read and approved the final manuscript.

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