

Interventions to prevent maternal obesity prior to conception, during pregnancy and postpartum.

Authors:

Mark Hanson, Institute of Developmental Sciences, University of Southampton and NIHR Southampton Biomedical Research Centre, University Hospital Southampton NHS Foundation Trust, UK

Mary Barker, MRC Lifecourse Epidemiology Unit, University of Southampton and NIHR Southampton Biomedical Research Centre, University Hospital Southampton NHS Foundation Trust, UK

Jodie M Dodd, Discipline of Obstetrics & Gynaecology and Robinson Research Institute, The University of Adelaide, and Women's and Babies Division, Women's and Children's Hospital, North Adelaide, South Australia

Shiriki Kumanyika, Department of Biostatistics and Epidemiology, University of Pennsylvania Perelman School of Medicine, Philadelphia, USA

Shane Norris, MRC/Wits Developmental Pathways for Health Research Unit, Department of Paediatrics, School of Clinical Medicine, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa

Eric Steegers, Department of Obstetrics & Gynaecology, Erasmus MC, University Medical Center Rotterdam, The Netherlands

Judith Stephenson, Department of Reproductive Health, Institute for Women's Health, University College London, and Children, Young People and Maternal Health Programme, UCLPartners Academic Health Science Partnership, London UK

Shakila Thangaratinam Women's Health Research Unit, Barts and the London School of Medicine and Dentistry, Queen Mary University of London, London UK

Huixia Yang, Department of Obstetrics and Gynecology, Peking University First Hospital, China.

Note on search criteria and methods used. We searched MEDLINE (2000-2015) using a range of relevant terms including weight, weight management, preconception, pre-pregnancy, pregnancy, post partum, gestational weight gain, lifestyle and maternal obesity in combination with "intervention" or "prevention". We mainly selected publications from the past 5 years, but did not exclude commonly highly regarded older publications. We also searched the reference lists of articles identified by this search strategy and other reviews and selected those we judged to be relevant. Review articles and book chapters are cited to provide readers with more details and more references than possible in this Review, which is not exhaustive.

Panel 1 - Key Messages

- Interventions to prevent obesity need to begin early in the life course, to reduce risk and optimise later responses to challenges, but also to be sustained through life stages and in different contexts.
- Preventing obesity in women of reproductive age before conception and between pregnancies will contribute substantially to achieving the Sustainable Development Goals, in terms of health, wellbeing, productivity and equity in the present and future generations.
- Current evidence suggests that antenatal dietary and lifestyle interventions for pregnant women who are overweight or obese, alone or in combination with pharmacological agents, are insufficient either to limit gestational weight gain to the degree required to have a meaningful impact on pregnancy and birth outcomes, or to reduce gestational diabetes. Interventions need to involve more than just the primary healthcare sector and may be more effective if linked preconception and postpartum interventions are integrated.

Improving health at this time in the life course needs to focus on generating individual capacity and capability to change diets and lifestyles by improving opportunity and motivation in individuals and communities. This requires a broader social movement that promotes preconception health, by generating bottom-up mobilisation of communities and individuals to complement the top-down approach from policy initiatives.

Abstract

It is now widely recognised that prevention of obesity in women of reproductive age is important both for their health and for that of their offspring. At present, weight control interventions in overweight or obese pregnant women, including drug treatment, have not been shown to produce sufficient impact on pregnancy and birth outcomes. This suggests that the focus for intervention should be on the preconception or post partum periods. Further research is needed on the longer-term effects of nutritional and lifestyle interventions before conception. Improving preconception health requires an integrated approach to pregnancy prevention, planning and preparation, involving more than just the primary healthcare sector and adopting an ecological approach to risk reduction which addresses personal to societal and cultural levels of influence. Raising awareness of the

period prior to pregnancy will require a new social movement involving generating ‘bottom-up’ mobilisation of communities and individuals complemented by a ‘top-down’ approach from policy initiatives. Intervening to reduce or prevent obesity at this time in the life course may contribute substantially to achieving the global Sustainable Development Goals, in terms of health, wellbeing, productivity and equity in the present and future generations.

1 Introduction

Accompanying papers in this series emphasise the adverse impact of preconception and maternal obesity on pregnancy outcomes, the health of the woman during pregnancy and later and on the transmission of obesity and risk of later non-communicable diseases (NCDs) to her offspring (for UK see ^{1,2}). The present paper addresses the question of how best to intervene to reduce such risk. Recent government reports which stress the health consequences of obesity in women of reproductive age (e.g. ³) emphasise the importance of a ‘whole of government’ approach to tackling the problem, coupled with a greater public awareness of the need for action at the level of both individuals and society. Such a combined ‘top-down’ and ‘bottom-up’ approach could make use of the substantial publicity surrounding the causes and consequences of obesity. Huang et al, in their paper in the recent Lancet series on obesity, articulate clearly how such a movement might be engineered to address the obesity crisis.⁴ In this paper we build on this framework, reviewing the nature of the interventions necessary and assessing what is known about their effectiveness during pregnancy and the periconceptual period. We then outline the components of a model for action to address unmet need in the prevention of obesity in the preconception period, with particular emphasis on linking bottom-up community and personal action and top-down health policy initiatives.

Current thinking about the prevention of NCDs, for which obesity is a major risk factor, stresses the importance of adopting a life course perspective ⁵ in addressing the trajectory of increasing risk. The trajectory is not only the result of accumulated pathological effects over time, but of environmental and other processes operating during sensitive periods of development, when responses to later challenges are partly set. ⁶ Thus while health at a time in the life course, e.g. on entering pregnancy, depends partly on the level of risk factors pertaining to the individual at that point, such as a woman’s current body mass index (BMI),

nutritional status, smoking and alcohol consumption, it also depends on her responses to physiological challenges such as diet, physical activity and the cardiovascular and metabolic demands of pregnancy. These are partly set up earlier in life.⁷ This raises the possibility that the most appropriate timing and type of interventions are those which optimise such maternal responses. In light of contraindications to implementing clinical weight loss programmes during pregnancy, preventing obesity in women of reproductive age before conception and between pregnancies is the approach of choice for optimizing both fetal and maternal health.⁸

2 Nature of interventions

A focus on prevention is consistent with the current paradigm for interventions to address obesity more generally.⁹ The rapid increases in obesity prevalence in diverse populations around the globe, in both children and adults and across socioeconomic strata, constitute a public health crisis.^{10,11,12} This 'epidemic' can be best understood as an inability of people, on average, to mount effective psychobiological or behavioural counter-responses to an increase in the societal forces that promote excess weight gain.^{13,14} These forces include urbanization, technological changes, and evolution of food systems and physical living environments in ways that result in: a) an increasing dominance of highly palatable and affordable manufactured foods with high fat and sugar content; b) food marketing strategies that involve widespread, intensive promotion of such foods; and c) environments and modern cultural norms such as sedentary jobs and dependence on cars that limit opportunities for routine physical activity and encourage sedentary behaviour.

In this scenario, public health approaches to curb and ultimately to reverse the obesity epidemic, that is, population-based obesity prevention, must be given a higher priority. The numbers of people affected by obesity already exceed the capacity of health care systems to provide effective management, even in high income countries. Where such treatment is available, persistent obesogenic environments oppose efforts to facilitate weight loss and prevent weight regain. Although primary health care providers clearly have a role in obesity prevention,^{15,16} interventions are also necessary in sectors outside health care systems.

These need to involve other aspects of society and government and address behaviour using methods beyond just one-to-one interactions with health care providers. As Mann et al point out,¹⁷ effective interventions do not rely solely on individual psychological capability and willpower; they promote health rather than merely focusing on bodyweight.

Ecological frameworks illustrate different levels at which interventions act to influence individual healthy eating, physical activity, and energy balance.^{18,19,20} These frameworks position individual behaviour as interacting with layers of surrounding influences, particularly proximal family and community characteristics, settings and relationships; these are, in turn, embedded within and influenced by more distal social, environmental and policy contexts (Figure 1).

Single or even sets of interventions may not effectively address obesity at any one level, and similarly actions at one level may not be effective without support or amplification from other levels.²¹ Viewed from a systems perspective, the variables and relationships in such ecological frameworks are aspects of complex adaptive systems in which elements are changing over time, and changes or interventions in one part influence and are influenced by changes or interventions in other parts of the system.²² Such frameworks assist with a) identifying the different levels, types, and focal points for interventions that need to interact in order to mitigate obesity promoting influences; b) considering how particular sets of interventions might be additive or mutually reinforcing; and c) anticipating potential undesirable consequences which may reduce efficacy or have unintended effects in other spheres.

When the goal is to prevent new cases of obesity from developing, types of prevention can be classified in terms of whether they are directed at: a) the entire population and are relevant to the layers of influence that include worksites, whole communities, government and industry; or b) selected individuals and demographic groups defined by age, ethnicity, or income, for example as being at a high risk of becoming obese; or c) are targeted at those who are already obese.¹³ In this context the reproductive phase of the life course represents a missed opportunity to improve public health, reducing the risk of obesity both in this and in the next generation. This paper therefore focuses on interventions during three phases of the life course: pre-conception, pregnancy and postpartum.

3 Current status of interventions to prevent or reduce maternal obesity in the preconception, pregnancy and postpartum periods

The risks associated with maternal overweight and obesity from a pregnancy and childbirth perspective are discussed in other papers in this series. They set the scene as to why interventions in pregnancy are important for improving immediate pregnancy outcomes in women and their children, as well as conferring longer-term benefits. As both high pre-pregnancy BMI and excessive gestational weight gain are associated with increased risk of adverse pregnancy outcomes, the focus of interventions has been on the antenatal period generally. For all the same reasons that they are important in pregnancy, these interventions need also to be extended or modified for application to the pre-conception and postpartum periods. In low and middle income countries this will need to involve adolescents, in view of the rising prevalence of obesity in younger people especially in these settings.

Interventions in Pregnancy

Lifestyle interventions

Lifestyle interventions for weight control can be divided into those that are diet-based, mainly physical activity-based and a mixture of diet- and physical activity-based. Currently, the National Institute for Health and Care Excellence in the UK recommends a healthy diet, and at least half an hour of physical activity daily to prevent excessive gestational weight gain in pregnancy. Women with BMI over 35 are recommended to obtain advice from a dietitian.²³ Physical activity plus dietary interventions are effective for weight management in pregnancy.²⁴ In a meta-analysis of interventions during pregnancy in overweight, obese and morbidly obese women, those delivered in early pregnancy on average showed better results than those delivered later in pregnancy.²⁵ An NIHR-commissioned systematic review on lifestyle interventions in pregnancy identified a statistically significant reduction in gestational weight gain (mean difference -1.42 kg, 95% CI -0.95 to -1.89 kg; $I^2 = 80\%$) among women who were provided with an intervention compared to those who received no intervention.²⁶ The effect of lifestyle interventions in pregnancy on gestational weight gain appeared consistent for women regardless of BMI category. Furthermore, there was a

suggestion of impact on clinical outcomes including pre-eclampsia, gestational diabetes, caesarean section, preterm birth and induction of labour.²⁷ However the studies included were mostly small, heterogeneous in terms of the intervention delivered, and in many instances outcomes were not reported by maternal BMI category. Furthermore, the majority of studies focussed on gestational weight gain as the primary outcome, with little reporting of other relevant pregnancy and birth outcomes. More recent reviews have cast doubt on the ability of lifestyle-based interventions initiated in pregnancy to reduce the incidence of gestational diabetes and pre-eclampsia.^{28,29} However, as noted above, such interventions are somewhat isolated and do not take account of the ecological framework described above. Behaviours might improve in an environment that provided support for them to be adopted and maintained.

In addition to the systematic reviews described above, there are important findings from the two largest, randomised trials conducted to date, both evaluating the impact of antenatal lifestyle interventions for pregnant women who are overweight or obese. These are the LIMIT and UPBEAT randomised trials described in more detail in Panel 2. Both trials, although carefully designed and carried out, demonstrate the limitations of diet and lifestyle interventions during pregnancy on pregnancy and birth outcomes. Other smaller evaluations of interventions to improve diet and body composition in obese pregnant women have been conducted, with mixed results. In a high risk group of women who had a history of GDM and/or were obese, the RADIEL study showed no reduction in gestational weight gain but a reduction in the incidence of GDM.³⁰ The LIP and TOP studies both achieved reductions in gestational weight gain but were not powered to detect differences in clinical outcomes such as decreases in rates of gestational diabetes.^{31,32}

Panel 2: UPBEAT and LIMIT lifestyle interventions with overweight and obese pregnant women

LIMIT and UPBEAT were large-scale, individually randomised controlled trials, testing the efficacy of using contacts with healthcare professionals during pregnancy to deliver intervention programmes to improve diet and physical activity levels and through this, reduce gestational weight gain and diabetes-related outcomes in mother and infant.^{33,34}

In LIMIT, 2212 overweight and obese pregnant women were randomised to receive individualised support at six points during pregnancy through a mixture of face-to-face and telephone contact with dietitians and trained research assistants vs. usual care.³⁵ They were encouraged to problem solve, set realistic goals and self-monitor in an intervention design guided by a Stages of Change model.³⁶ The trial demonstrated no reduction in the proportion of babies born large-for-gestational-age (birth weight at or above the 90th centile for gestation and sex, the primary outcome) but a significant improvement in scores on a healthy eating index and in other indicators of dietary quality which were sustained throughout pregnancy, along with an increase in total physical activity. While there was no effect on gestational weight gain, women who received the intervention were significantly less likely to give birth to an infant with weight above 4kg (a secondary outcome).

UPBEAT was a trial of intensive behavioural support for diet and lifestyle improvement in 1555 obese pregnant women, designed to reduce the incidence of gestational diabetes and of large-for-gestational-age infants. UPBEAT drew on control theory and social cognitive theory in the design of the intervention.³⁷ Women in the intervention arm of the trial were offered an initial interview plus eight group or individual sessions delivered face-to-face or over the phone by a trained practitioner, who supported them to problem-solve, set goals, self-monitor and enlist social support in attempting to develop a healthier pattern of eating. Dietary recommendations were tailored to the woman's habitual diet, and were designed to reduce glycaemic load. Physical activity advice focused on incremental increases in walking, tailored to pre-existing activities. The authors reported no differences in incidence of gestational diabetes or babies born large for gestational age.³⁴ They did show, however, reduced dietary glycaemic load, energy intake, carbohydrate, and total fat, and increased protein and fibre intake and physical activity, and produced a modest but statistically significant 0.6kg reduction in gestational weight gain.

Importantly, both of these large-scale trials were adequately powered to identify differences in clinical outcomes for women and their infants, although no such differences were detected. They did not show any change in rates of fetal growth restriction, and neither did the interventions have a beneficial effect on other fetal and neonatal outcomes such as large for gestational age fetus, admission to the neonatal intensive care unit, birth trauma and hyperbilirubinaemia.

The fact that these changes in diet and physical activity did not translate into improvements in the pregnancy outcomes led the authors of UPBEAT to conclude that even successful diet and lifestyle interventions in pregnancy may not be sufficient to reduce the likelihood of

gestational diabetes or to improve insulin sensitivity in women who enter pregnancy already obese. This suggests that maternal overweight and obesity are best addressed across the entire reproductive life cycle and that all women of child-bearing age need to be encouraged to adopt healthy diets and lifestyles prior to and between conceptions.

Overall, reviews suggest that despite a modest beneficial effect of diet and lifestyle interventions on gestational weight gain, there is little evidence from aggregated data from randomised clinical trials of significant associations between reduction in gestational weight gain, and rates of pre-eclampsia, gestational diabetes and induction of labour.³⁸ The UPBEAT study described in Panel 2 is an example of a well-executed study that has not shown improvements in pregnancy outcomes in obese women, despite statistically significant reductions in gestational weight gain, though it is possible that there may be longer-term benefits or positive epigenetic changes for the mothers or babies. The extent to which an individual can change their behaviour in an environment which is not supportive of eating well and being active will inevitably be limited. It may be that far greater reductions in gestational weight gain could be achieved in a more enabling environment.

One of the main challenges encountered in lifestyle behaviour change studies has been compliance, with up to 25% of all women not engaging with the intervention provider.³⁹ This may be particularly true of interventions promoting physical activity in obese pregnant women.³⁹ Women cite physical inconvenience, the limitations of being pregnant and lack of time as explanations for stopping exercise during pregnancy.⁴⁰ Whilst there is now a substantial literature that identifies the components of effective diet and lifestyle interventions,⁴¹ the major challenge remains of how best to engage pregnant women in improving their diets and lifestyles and how to sustain their engagement post-partum. One method of engagement currently showing some promise is the use of digital platforms to promote diet and lifestyle improvement both during pregnancy but also in the preconception period.⁴²

Pharmacological and other interventions

Women who are overweight or obese enter pregnancy in a state of increased insulin resistance, which raises the possibility that drugs such as metformin could be used as an adjunct therapy to improve insulin sensitivity and the pattern of fetal growth. Recent randomized trials of metformin in obese pregnant women with no pre-existing diabetes failed to demonstrate a beneficial effect on birth weight, gestational weight gain, gestational diabetes, or on the combined fetal and neonatal outcomes of stillbirth,

termination of pregnancy, miscarriage and neonatal death. ^{43,44,45} Further studies of metformin use in pregnancy are however currently in progress.

Nutritional supplements such as probiotics have been administered in pregnancy because of their potential beneficial effect in altering the gut microbiome, and thereby modifying lipopolysaccharides and insulin sensitivity. ²⁸ Two randomized trials evaluated probiotic administration alongside dietary intervention, and have shown benefit in reducing gestational diabetes. ⁴⁶ A short, four-week course of probiotics during pregnancy in obese women has not shown any improvement in glycaemic status, however, compared to obese controls. ⁴⁷

Together, these findings suggest that provision of antenatal dietary and lifestyle interventions for pregnant women who are overweight or obese, alone or in combination with pharmacological agents, are insufficient to either reduce gestational weight gain to the degree required to have a meaningful impact on pregnancy and birth outcomes, or to reduce gestational diabetes. However, the impact of such interventions on subsequent child obesity remains to be determined, with both the LIMIT and UPBEAT trials continuing to follow-up participants into early childhood. The initial outcome of these trials suggests that it may be most effective to intervene either prior to conception or between pregnancies to improve maternal and infant health in the short term and population health in the longer term. The NIHR funded Individual Patient Data (IPD) meta-analysis co-ordinated by the International Weight Management in Pregnancy (i-WIP) Collaborative Network evaluates the differential effects of diet and lifestyle interventions in pregnancy, and plans to publish its finding shortly (<http://www.nets.nihr.ac.uk/projects/hta/120150>).

Interventions in the preconception and postpartum periods

There are a number of Cochrane systematic reviews addressing aspects of preconception health for women in relation to subfertility, ⁴⁸ diabetes, ⁴⁹ as well as reducing post-partum weight retention ⁵⁰ and general pre-pregnancy health promotion. ⁵¹ In the context of a preconception outpatient clinic in a high income country, the advantages of healthy diet and lifestyle in the preconception period have been promoted in terms of fertility and reducing miscarriage. ^{52,53} There are, however, few interventions in the preconception period aimed

at targeting maternal obesity, and in fact only a very short list of effective interventions for a range of outcomes in this period, largely concerning smoking cessation, folic acid supplementation, diet and offspring birthweight.⁵⁴ The Cochrane systematic review by O'Pray and colleagues,⁵⁵ focused specifically on pre-pregnancy interventions to promote weight loss in women who are overweight or obese, but failed to identify any randomised trials, highlighting the current dearth of high quality information available relating to this area of preconception care. Other more general reviews of preconception care have been produced.^{56,57,58,59,60}

There is a slightly longer list of interventions that have focussed on the postpartum period which for many women may also represent a period between conceptions. Two reviews identified 10 trials of diet and/or physical activity interventions that aimed to reduce body weight postpartum.^{61,62} Overall, the reviews concluded that interventions were successful, with some suggestion that those that combine diet and physical activity with an element of supervision or professional support were the most effective. It is not clear, however, when during the postpartum period it is most effective to intervene, or at what point between pregnancies weight loss might be most beneficial for the mother and her future offspring. Exclusive breastfeeding has also been shown in some studies to increase the probability of returning to pre-pregnancy weight and BMI in the postpartum period.^{63,64} The effectiveness of this as a weight loss strategy postpartum, however, seems to depend on the timing of measurements and whether or not breastfeeding is exclusive.⁶⁵

As noted in 2015 in the annual report of the Chief Medical Officer for England³, the literature on preconception health and care overlaps with that on for pregnancy and postpartum^{54,56,57,58}. This is largely observational, and shows adverse effects of a range of disease and unhealthy behaviours on pregnancy outcomes. For example, smoking during pregnancy is associated with higher rates of miscarriage, placental abruption, low birth weight and preterm birth; poor glycaemic control in women with diabetes is associated with increased risk of miscarriage, obstetric complications (macrosomia and shoulder dystocia) and major congenital abnormalities. In contrast, there are a very few studies showing benefits on birth outcomes of intervention to reduce risk *before* pregnancy. The most well established examples are folic acid supplementation and improved glycaemic control in

women with diabetes, shown in randomised trials to reduce the incidence of birth defects.

66

A recent systematic review of preconception risks and meta-analysis of the effectiveness of pre-conception interventions confirms the potential for substantial health gain for women and their families from intervention in this period.⁶⁷ Such interventions range from a general health promotion approach (maintaining a healthy weight, eating a healthy diet, smoking cessation, etc.) coupled with other interventions that are more specific to the preconception period, such as folic acid⁶⁸ and multivitamin supplementation, to more personalised approaches for women with chronic disorders, such as optimising diabetes control,⁶⁹ review of potentially harmful medication and genetic counselling. Given the challenges of conducting randomised trials to examine the effect of preconception interventions on birth outcomes, which include identifying, recruiting and following-up women before as well as after they become pregnant, it is not surprising that very few such trials have been completed.

There are few studies, variously termed applied health research, health policy research or implementation science, of methods for implementing or delivering effective preconception interventions in clinical practice. A health policy review of preconception care in England (Stephenson et al Preconception Care in England. Dept of Health 2012) concluded that the biggest gap in evidence related to implementation of pre-conceptio interventions into practice. The issue of how women prepare for pregnancy⁷⁰ naturally leads to the question of whose responsibility it is to provide advice and preconception care. When this question was posed to a range of UK health professionals, most answers pointed to primary care, although the primary care professionals felt that they were seldom involved in preconception care.⁷¹ In the UK and many other countries, current health services are organised around preventing unintended pregnancy in family planning clinics or screening for and managing medical conditions in pregnancy, with little consideration of planning, contraception and preparation for pregnancy before and between conceptions. A more integrated approach or 'continuum of care' that encompasses prevention of unintended pregnancy, planning and preparation is needed.⁷²

4 Addressing unmet need in preconception interventions

In 2015, the Chief Medical officer for England recommended that the UK Government includes obesity in its national risk planning.⁷³ Given the small impact of diet and lifestyle pregnancy interventions on obesity-related outcomes for both the woman and her infant, attention now needs to be re-focused on the preconception period as a potentially more effective time to intervene. Recent policy initiatives^{74,75} have therefore focused on adolescents⁷⁶ and women of reproductive age as an important target for improving maternal health and the health of the next generation. This emphasis is important in light of increases in obesity in adolescent girls in low- and middle-income countries.⁷⁷

The increase in chronic disease in the face of a tide of health messages is powerful evidence that the information-giving and education mandated in many policy initiatives are insufficient to mobilise women and communities to change their diets and lifestyles. As Huang and others have pointed out, for campaigns to be maximally effective the top-down approach involving policy initiatives has to be complemented by the bottom-up mobilisation of communities and individuals.⁴ Figure 2 shows an integration of Huang's conceptualisation of the processes of mobilising communities with the COM-B model of individual behaviour change.⁷⁸ The COM-B model proposes that behaviour is a product of the individual having the capability (C), the opportunity (O) and the motivation (M) to perform that behaviour (B), and that if any of these are missing then s/he will not behave in the way we might expect. We contend that both the mobilising of communities and individual capacity are necessary to improve health and nutritional status prior to conception. Figure 2 illustrates how a new initiative might give individuals and communities the capacity to act in order to reduce preconception and maternal obesity.

Huang et al's analysis explains how creating policy initiatives can shape demand, but demand also enables policies to be put into action. It also suggests that consistent advocacy activity is necessary to optimise individuals' and communities' responses to implementation of policies. These activities involve a wide range of media, academic opinion leaders and professional bodies, NGOs including charities, and patient groups. Experience shows that such campaigns or social movements can achieve policy changes at local and central

government levels.⁷⁹ If these are seen to lead to both deliverable and affordable activities which accord with public pressure for action, then barriers to a new top-down component may be removed, i.e. the political will to institute change is generated. In many settings, the healthcare, educational and other components of a platform needed to supply the demand for the intervention are already in place, so that the political will drives closer integration of action rather than the establishment of new services. In the UK for example, linking of contraception, pregnancy planning and antenatal services would provide greater continuity in achieving behaviour change in adolescent and young women.³ Additional links between formal education, outside school community-based activities and public health support would strengthen this 'advocacy coalition' and further support the generation of a new preconception service, promoting integration of existing services and providing opportunities for individual women to improve their preconception health.^{70,80} The value of this reciprocal approach between levels of influences and between actions of the individual and the impact of the environment was articulated clearly with respect to overall obesity prevention in a previous Lancet series.⁸¹

The goal of this approach to improving preconception health is to move from merely providing information about health issues to women of reproductive age and their partners, through changing attitudes and increasing motivation for behaviour change, to empowering individuals with the capacity to act. Interestingly, this kind of bottom-up activity to improve preconception health is being trialled in some low and middle income countries. Here, because obesity coexists with undernutrition, focusing on health as opposed to only on obesity is important. The underweight woman who becomes pregnant is also at high risk of complications. The Ntshembo intervention in South Africa focuses on adolescent health broadly, in order to address both underweight and overweight adolescents, and employs specialised community health workers trained to promote health literacy and behaviour change in individuals coupled with peer and family support and within the context of community mobilisation.⁸²

Community mobilisation and individual action to improve preconception health

Discussions with groups of young women in the UK and USA suggest that in such high income countries most know that they and their children need to eat a balanced and varied diet and to engage in regular physical activity.^{83,84} Those who struggle to make healthy choices for themselves and their children say that they feel out of control of both their diets and their lives, which are governed by more important priorities such as coping with the multiple challenges of running their households. This is particularly true for food. Women report that their partners and children dictate what they eat, and that the cost of food means that they only buy what they know will be eaten. Given the other demands in their lives, they have no energy for the battle involved in creating good eating habits in their children and they get little support from their partners.^{85,86} If the nutritional status of women of child-bearing age is to be improved and maternal obesity addressed, they have to be empowered to take control of their lives; they need to have greater individual capacity to act; and their partners need to be enlisted in the initiative.⁸⁷ The need to increase individuals' capacity to act as well as to make the immediate environment more supportive of that action has been recognised in interventions to support physical activity. Focus groups with adolescent girls and with staff from their schools in South Africa suggested that schools needed resources and that staff from schools and other school-related organisations needed training, in addition to the girls' needs for empowerment in relation to their body image and support from parents if they were to become more physically active.⁸⁸

As described above, communities as well as individuals need to be mobilised in order to create a demand for maternal obesity prevention policies and for better access to better food for women of child-bearing age. Behavioural theory suggests that individual capacity to act, sometimes called agency or self-efficacy, and community empowerment have a reciprocal relationship and that empowered communities create empowered citizens and *vice versa*.⁸⁹ Increases in self-efficacy, i.e. a sense of being able to achieve desired goals in life and behaviour, are a prerequisite for taking control and, conversely, taking control builds self-efficacy. In the Wessex region of the UK and in the maternal and child workforce in New Zealand, 'healthy conversation' techniques have been harnessed by training health and social care staff to have empowering consultations and promote self-efficacy as part of their routine interactions with young women

<http://www.wessexphnetwork.org.uk/media/26776/mecc-briefing-paper.pdf>,

<http://www.healthystartworkforce.auckland.ac.nz/en/our-education-programmes/healthyconversations.html>) Empowerment is achieved through assisted

problem-solving and goal-setting.⁹⁰ Trials have shown that health and social care staff can conduct such conversations as part of their practice and that they may have a protective or even amplifying effect on women's sense of self-efficacy, and ultimately their capacity to act.

⁹¹ Training health and social care staff in skills to support behaviour change has the capacity to reach the large number of people with whom they have daily interactions, and can be adopted in any country and in any setting.

This kind of approach has been used to mobilise communities of women to empower them to take control of their health and that of their children to great effect in low and middle income countries. For example, in a programme in rural villages in Nepal, women came together to share their experiences, identify common problems in child-rearing, and generate solutions that would work in their own communities.⁹² These meetings, which amounted to facilitated conversations, were associated with a reduction of 30% in neonatal and of 80% in maternal deaths in these villages, figures which have since been replicated.⁹³

Part of the success of the projects of Prost et al in improving maternal and child health came from mobilising communities to seek solutions to problems which they had themselves identified. Ways of mobilising communities therefore need to be found that increase capacity to create environments that support women to make better choices for themselves and their families. To do this we need to extend an empowering style of communication with commercial and political organisations. If a community can generate consensus, it puts pressure on both politicians to respond to voters, and on the commercial organisations to cater for their customers. Huang et al propose 'advocacy coalitions' in their analysis of methods of mobilising public support for policy actions to prevent obesity.⁴ Applying this analysis to advancing preconception health and prevention of maternal obesity as a social movement suggests a process of identifying political opportunities and definition of common goals, followed by sustained collective action to generate a popular demand for policies and political actions that support preconception health and address the challenge of obesity.

There are existing examples where community mobilisation has been used specifically to support improvements in preconception health. In the Netherlands the city of Rotterdam financed the local program 'Ready for a Baby'⁹⁴ and the Ministry of Health, Welfare and Sport funded the national program 'Healthy Pregnancy for All' in 14 other Dutch cities.⁹⁵ Panel 3 describes project elements and the way in which 'Healthy Pregnancy 4 All' came into being.

Panel 3

'Ready for a Baby' and 'Healthy Pregnancy 4 All': preconception health programmes in the Netherlands

Following a public and political debate stimulated by recognition of the relatively high national perinatal mortality rates and of large inequalities in perinatal health between poor immigrant and wealthier native areas, the promotion of healthy pregnancies has become a priority in The Netherlands. Advocacy activity was initiated by a university research team in Rotterdam. Conducting analysis using routinely collected data and city maps to demonstrate the huge disparities in perinatal mortality and morbidity in the city, they engaged local government officials in a dialogue which led to the conclusion that action was required. This 'societal valuing' of knowledge previously held in an academic institution led to the conviction amongst policy makers and care providers that "things should be done better" and "better, new things should be done" to improve preconception care. As a result, the municipality of Rotterdam in 2008 financed a 1.7 million Euro programme 'Ready for a Baby'. This included trialing the introduction of a programme of preconception and interconception care and also involved holistic assessment of non-medical as well as medical risks in women at first visit to a pregnancy care giver . Care was then tailored to the individual in a shared care model including community midwives, obstetricians and public health providers. Particular efforts were made to reach women of lower educational attainment and immigrant groups. One way in which this was done was to involve local social networks and migrant organisations and to engage specially trained peer group educators to promote preconception health. Through holding peer-led education sessions in homes and in local places such as mosques, over 2000 people have been reached so far. At the core of programme is an office, consisting of two project managers—one appointed by the municipal health care services and one by the Erasmus University Medical Centre - a number of program advisers and a communication team. Stakeholders from medical, public health and social welfare domains are integral to the programme. The target is to reduce perinatal mortality to the national average in ten years, and for the first time in the

Netherlands, preconception healthcare is formally part of municipal policy, on which progress has to be reported every five years.

The 'Ready for a Baby' programme was taken up by the Dutch Ministry of Health, Welfare and Sport in order to address inequalities and improve perinatal health at a national level. Fundamental to this national programme, called 'Healthy Pregnancy for All' and initiated in 2011, is the linking of services to produce a chain of preconception, antenatal, maternity and child care. This Ministry committed 4.8 million Euro in a two-staged, 6 year project designed by the Erasmus Medical Center and based on epidemiological analyses of national data identifying municipalities in which perinatal mortality and morbidity were high. Fourteen cities were originally identified and targeted for maximal effect. Local government was engaged through presentation of data using the same kind of maps of perinatal mortality and morbidity as used in Rotterdam, and a process of creating consensus among local policy makers and care providers was begun. The project includes a prospective community-based cohort study on the effectiveness of a programme of preconception care. Furthermore, a cluster randomized trial is conducted on systematic risk assessment at pregnancy booking (including both medical and non-medical risk factors) followed by a shared care approach by community midwives and obstetricians using patient-tailored multidisciplinary care pathways. In some areas, the programme is being extended to use the periods of antenatal and maternity care to identify families and children at particular social risk and involve children's services where necessary, and to use routine visits after the birth to offer inter-conception care. The research team are due to report on the outcomes of the studies in 2016 and 2018.

An essential component of these Dutch programs is enhanced pre- and postpartum care. The authors explain that it has been a major challenge not only to raise public awareness of preconception care, but also to reach the most vulnerable population groups including youth. In mobilising the community and in supporting these groups, it has been important to offer preconception care in combination with public health and social welfare services.⁹⁶

A combination of this type of 'bottom-up' approach with the findings from the large-scale RCTs described earlier in this paper could produce an excellent and effective intervention to improve preconception health and promote health equity. Such RCTs demonstrate the efficacy of support for improving diet and increasing physical activity of women in pregnancy. The controlled setting of these RCTs allows us to identify precisely what is required to achieve change in tightly defined outcomes and the mechanisms underlying this change. In order to capitalise on the value of RCTs they need to be translated into the community setting. Improving preconception health will therefore necessitate: increasing community awareness of the need to improve preconception health; defining outcomes that are important to them; exploiting greater awareness to generate motivation to change; and co-creating the structures to deliver and monitor an effective intervention. The potential of such an approach which combines learning from RCTs and community mobilisation has yet to be realised.

Postpartum care was one of the components of the US national 'Healthy Start Program', a community-based initiative designed to eliminate disparities in infant mortality and other adverse birth outcomes. Activities included outreach, case management, local health system action plans and sustainability planning. Collectively the interventions were intended to help improve access to care and birth outcomes by enhancing health literacy, promoting healthy behaviours and mobilizing the community to improve perinatal health through delivery of social and medical services to support women between and during pregnancies and also their infants.⁹⁷ Local evaluations of the programme have shown reductions of approximately 30% in very low birth weight and in preterm births in disadvantaged communities.⁹⁸

Policies to support improvement of preconception and postpartum health

Intervening in the preconception period can benefit two generations. With the exception of folic acid supplementation, rubella vaccination, genetic counselling and drugs, generating support for preconception care in terms of nutrition and lifestyle is sometimes viewed as the same as for any general health improvement campaign. The distinction lies only in the specific purpose of the intervention and the target group at which it is aimed. The number and scope of policies that have potential to impact on preconception health is therefore large. There is now a major international focus on this phase of the life course, as featured in the report of the Director-General of WHO's Commission on Ending Childhood Obesity (<http://www.who.int/end-childhood-obesity/en/>) and in the Global Strategy on Women's, Children's and Adolescents' Health produced under the aegis of the United Nations Secretary-General's Every Woman Every Child initiative (<http://globalstrategy.everywomaneverychild.org/>). The latter emphasises the potential health and economic benefits which could result from a new focus on adolescent health for current and future generations. This theme is also picked up in the Sustainable Development Goals (<http://www.un.org/sustainabledevelopment/sustainable-development-goals/>), which refer to the importance of prevention of NCDs (Target 3.4) and to addressing the nutritional needs of adolescent girls, pregnant and lactating women (Target 2.2). International professional organisations such as the International Federation of Gynecology and Obstetrics (FIGO) have focused on this area in relation to adolescent, preconception and maternal nutrition.⁹⁹ At the national level the challenge of obesity in the preconception, pregnancy and lactation periods is highlighted in the Chief Medical Officer for England's annual report (CMO 2014). Each of these documents endorses the need for women to be actively involved in the initiative, the 'bottom up' approach we refer to above. This requires integration of two extant movements of which one (addressing obesity) is currently much more 'top down' than the other (promoting women's health).

The reproductive years of a woman's life course offer an as yet under-utilised opportunity to engage her and her partner in promoting their health and that of their future children. The journey from pregnancy prevention, to pregnancy planning, pregnancy preparation and preparing for parenthood (the four Ps in the Chief Medical Officer for England's annual

report³) brings them into contact with a range of health care providers, including GPs, nurses, pharmacists, community midwives, health visiting teams, and sexual and reproductive health specialists. Development and enactment of policies to ensure that professionals in each of these groups are trained in the skills needed to engage the woman and her partner with the issues, to offer support with the problem of overweight and obesity, and then to liaise with the other appropriate services, would provide sustained and integrated provision of preconception care. A large-scale randomised trial would be required to test the effectiveness of such a service.

Conclusion

High quality antenatal dietary and lifestyle intervention trials in overweight or obese pregnant women, alone or in combination with pharmacological agents, have not been shown to limit gestational weight gain to the degree required to have a meaningful impact on pregnancy and birth outcomes, or to reduce incidence of gestational diabetes. This suggests that the focus for interventions should be the preconception or postpartum periods. This requires a broader social movement that generates bottom-up mobilisation of communities and individuals, to create demand, coupled with a top-down approach from policy initiatives to provide supply of services. However, generating the political will for policy change requires considerable advocacy activity, which again needs to be driven by public awareness and demand. In addition to the health benefits for women and their children, such an initiative would provide economic, humanitarian and equity benefits, and may contribute substantially to achieving the Sustainable Development Goals.

To quote David Barker in the address he gave at the UK Medical Research Council's centenary event in 2013, "The greatest gift we could give to the next generation is to improve the nutrition and growth of girls and young women. The next generation does not have to suffer from heart disease, osteoporosis, breast cancer. They are unnecessary diseases which did not exist a hundred years ago. We could readily prevent them had we the

will to do so.” Intervening to prevent maternal obesity prior to conception and postpartum will be a critical part of such a gift.

References

1. Heslehurst N, Rankin J, Wilkinson JR, Summerbell CDA nationally representative study of maternal obesity in England, UK: trends in incidence and demographic inequalities in 619 323 births, 1989-2007. *Int J Obes* 2010; **34**: 420-428.
2. Health and Social Care Information Centre (2013). Health Survey for England 2013.
3. Davies SC. Annual report of the Chief Medical Officer, 2014, The health of the 51%: Women. London: Department of Health 2015
4. Huang TT, Cawley JH, Ashe M et al. Mobilisation of public support for policy actions to prevent obesity. *Lancet* 2015; **385**: 2422-2431.
5. Kuh D, Shlomo YB. A Life course approach to chronic diseases epidemiology. USA, Oxford University Press 2004
6. Hanson MA, Gluckman PD. Early developmental conditioning of later health and disease: physiology or pathophysiology? *Physiol Rev* 2014; **94**: 1027-1076.
7. Li Y, Ley SH, Tobias DK et al. Birth weight and later life adherence to unhealthy lifestyles in predicting type 2 diabetes: prospective cohort study. *BMJ* 2015; **351**: h3672.
8. Institute of Medicine and National Research Council. Weight Gain During Pregnancy. Reexamining the Guidelines __ Washington, DC., National Academies Press. 2009
9. Gortmaker SL, Swinburn BA, Levy D et al. Changing the future of obesity: science, policy, and action. *Lancet* 2011; **378**: 838-847.
10. Finucane MM, Stevens GA, Cowan MJ et al. National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. *Lancet* **2011**; **377**: 557-567.
11. Subramanian SV, Perkins JM, Ozaltin E, Davey Smith g. Weight of nations: a socioeconomic analysis of women in low- to middle-income countries. *Am J Clin Nutr* 2011; **93**: 413-421.
12. Wang Y, Lim H. The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. *Int Rev Psychiatry* 2012; **24**: 176-188.
13. World Health Organization. Obesity. Preventing and Managing the Global Organization. Report of a WHO Consultation. WHO Technical Report Series 894. Geneva, World Health Organization. 2000
14. Kumanyika SK, Obarzanek E, Stettler N et al. Population-based prevention of obesity: the need for comprehensive promotion of healthful eating, physical activity, and energy

balance: a scientific statement from American Heart Association Council on Epidemiology and Prevention, Interdisciplinary Committee for Prevention (formerly the expert panel on population and prevention science). *Circulation* 2008; **118**: 428-464.

15. Kushner RF, Ryan DH. Assessment and lifestyle management of patients with obesity: clinical recommendations from systematic reviews. *JAMA* 2014; **312**: 943-952
16. Ard J. Obesity in the US: what is the best role for primary care? *BMJ* 2015; **350**: g7846
17. Mann T, Tomiyama AJ, Ward A. Promoting Public Health in the Context of the "Obesity Epidemic": False Starts and Promising New Directions. *Perspect Psychol Sci* 2015; **10**: 706-710.
18. Booth SL, Sallis JF, Ritenbaugh C et al. Environmental and societal factors affect food choice and physical activity: rationale, influences, and leverage points. *Nutr Rev* 2001; **59**(3 Pt 2): S21-39; discussion S57-65.
19. Wetter AC, Goldberg JP, King AC et al. How and why do individuals make food and physical activity choices? *Nutr Rev* 2001; **59**: S11-20; discussion S57-65.
20. Institute of Medicine. Preventing Childhood Obesity. Health in the Balance. Washington, DC, National Academies Press 2005
21. Huang TT, Drewnoski A, Kumanyika S, Glass TA. A systems-oriented multilevel framework for addressing obesity in the 21st century. *Prev Chronic Dis* 2009; **6**(3): A82.
22. Hammond RA. Complex systems modeling for obesity research. *Prev Chronic Dis* 2009; **6**: A97.
23. National Institute for Health and Clinical Excellence. Weight management before, during and after pregnancy. Public health guidelines. Manchester, UK, National Institute for Health and Clinical Excellence. **PH27** 2010
24. Choi J, Fukuoka Y, Lee JH. The effects of physical activity and physical activity plus diet interventions on body weight in overweight or obese women who are pregnant or in postpartum: a systematic review and meta-analysis of randomized controlled trials. *Prev Med* 2013; **56**: 351-364.
25. Agha M, Agha RA, Sandall J. Interventions to reduce and prevent obesity in pre-conceptual and pregnant women: a systematic review and meta-analysis. *PLoS One* 2014; **9**: e95132
26. Thangaratinam S, Rogozinska E, Jolly K et al. Interventions to reduce or prevent obesity in pregnant women: a systematic review. *Health Technol Assess* 2012; **16**: iii-iv, 1-191
27. Thangaratinam S, Rogozinska E, Jolly K et al. Effects of interventions in pregnancy on maternal weight and obstetric outcomes: meta-analysis of randomised evidence. *BMJ* 2012; **344**: e2088

28. Allen R, Rogozinska E, Sivarajasingam P, Khan KS, Thangaratinam S. Effect of diet- and lifestyle-based metabolic risk-modifying interventions on preeclampsia: a meta-analysis. *Acta Obstet Gynecol Scand* 2014; **93**: 973-985.
29. Rogozinska E, Chamillard M, Hitman GA, Khan KS, Thangaratinam S. Nutritional manipulation for the primary prevention of gestational diabetes mellitus: a meta-analysis of randomised studies. *PLoS One* 2015; **10**: e0115526.
30. Koivusalo SB, Rönö K, Klemetti MM et al. Gestational Diabetes Mellitus Can Be Prevented by Lifestyle Intervention: The Finnish Gestational Diabetes Prevention Study (RADIEL) A Randomized Controlled Trial. *Diabetes care* 2016; **39**:24-30.
31. Vinter CA, Jensen DM, Ovesen P, Beck-Nielsen H, Jorgensen JS. The LiP (Lifestyle in Pregnancy) study: a randomized controlled trial of lifestyle intervention in 360 obese pregnant women. *Diabetes care* 2011; **34**:2502-7.
32. Renault KM, Norgaard K, Nilas L et al. The Treatment of Obese Pregnant Women (TOP) study: a randomized controlled trial of the effect of physical activity intervention assessed by pedometer with or without dietary intervention in obese pregnant women. *Am J Obstet Gynecol* 2014; **210**: 134.e1-9
33. Dodd JM, Turnbull D, McPhee AJ et al. Antenatal lifestyle advice for women who are overweight or obese: LIMIT randomised trial. *BMJ* 2014; **348**: g1285.
34. Poston L, Bell LR, Croker H et al. Effect of a behavioural intervention in obese pregnant women (the UPBEAT study): a multicentre, randomised controlled trial. *Lancet Diabetes Endocrinol* 2015; **3**: 767-777.
35. Dodd JM, Cramp C, Sui Z et al. The effects of antenatal dietary and lifestyle advice for women who are overweight or obese on maternal diet and physical activity: the LIMIT randomised trial." *BMC Med* 2014; **12**: 161.
36. Prochaska JO, DiClemente CC. Transtheoretical therapy: toward a more integrative model of change. *Psychotherapy: theory, research and practice* 1982; **19**: 276-288
- 37.
38. Bandura A. Self-efficacy: the exercise of control. New York, W.H. Freeman and Company. 1997
Ruifrok AE, van Poppel MN, van Wely M et al. Association between weight gain during pregnancy and pregnancy outcomes after dietary and lifestyle interventions: a meta-analysis. *Am J Perinatol* 2014; **31**(5): 353-364.
39. Poston L, Briley AL, Barr S et al. Developing a complex intervention for diet and activity behaviour change in obese pregnant women (the UPBEAT trial); assessment of behavioural

change and process evaluation in a pilot randomised controlled trial. *BMC Pregnancy Childbirth* 2013; **13**: 148

40. Oostdam N, van Poppel MN, Wouters MG et al. No effect of the FitFor2 exercise programme on blood glucose, insulin sensitivity, and birthweight in pregnant women who were overweight and at risk for gestational diabetes: results of a randomised controlled trial. *BJOG* 2012; **119**: 1098-1107.
41. Michie S, Abraham SC, Whittington C, McAteer J, Gupta S. Effective techniques in healthy eating and physical activity interventions: a meta-regression. *Health Psychol* 2009; **28**: 690-701
42. Van Dijk MR, Huijgen NA, Willemsen SP, Laven JS, Steegers E, Steegers-Theunissen RP. m-Health improves nutrition and lifestyle of the reproductive population. *Journal of Medical Internet Research* 2016; **In Press**
43. Chiswick CA, Reynolds RM, Denison FC et al. Efficacy of metformin in pregnant obese women: a randomised controlled trial. *BMJ Open* 2015; **5**(1): e006854.
44. Chiswick C, Reynolds RM, Denison F et al. Effect of metformin on maternal and fetal outcomes in obese pregnant women (EMPOWaR): a randomised, double-blind, placebo-controlled trial. *Lancet Diabetes Endocrinol* 2015; **3**: 778-786.
45. Syngelaki A, Nicolaides KH, Balani J et al. Metformin versus Placebo in Obese Pregnant Women without Diabetes Mellitus. *N Engl J Med* 2016; **374**: 434-443.
46. Luoto R, Laitinen K, Nermes, M, Isolauri E. Impact of maternal probiotic-supplemented dietary counselling on pregnancy outcome and prenatal and postnatal growth: a double-blind, placebo-controlled study. *Br J Nutr* 2010; **103**(12): 1792-1799.
47. Lindsay KL, Kennelly M, Culliton M et al. Probiotics in obese pregnancy do not reduce maternal fasting glucose: a double-blind, placebo-controlled, randomized trial (Probiotics in Pregnancy Study). *Am J Clin Nutr* 2014; **99**: 1432-1439.
48. Anderson K, Norman RJ, Middleton P. Preconception lifestyle advice for people with subfertility. *The Cochrane Library* 2010.
49. Tieu J, Middleton P, Crowther CA. Preconception care for diabetic women for improving maternal and infant health. *Cochrane Database Syst Rev* **12 2010**
50. Amorim Adegboye AR, Linne YM, Lourenco PMC. Diet or exercise, or both, for weight reduction in women after childbirth. *The Cochrane Library* 2007
51. Whitworth M, Dowswell T. Routine pre Library both, for weight reduction in women after childbirth *The Cochrane Library* 2009

52. Hammiche F, Laven JS, van Mil N, de Cock M, de Vries JH, Lindemans J, Steegers EA, Steegers-Theunissen RP. Tailored preconceptional dietary and lifestyle counselling in a tertiary outpatient clinic in The Netherlands. *Hum Reprod* 2011; **26**: 2432-2441
53. Twigt JM, Bolhuis ME, Steegers EA, Hammiche F, van Inzen WG, Laven JS, Steegers-Theunissen RP. The preconception diet is associated with the chance of ongoing pregnancy in women undergoing IVF/ICSI treatment. *Hum Reprod* 2012; **27**: 2526-2531.
54. Temel S, van Voorst SF, Jack BW, Denktas S, Steegers EA. Evidence-based preconceptional lifestyle interventions. *Epidemiol Rev* 2014; **36**: 19-30
55. Opray N, Grivell RM, Deussen AR, Dodd JM. Directed preconception health programs and interventions for improving pregnancy outcomes for women who are overweight or obese. The Cochrane Library 2014
56. Johnson K, Posner SF, Biermann J et al. Recommendations to improve preconception health and health care--United States. A report of the CDC/ATSDR Preconception Care Work Group and the Select Panel on Preconception Care. *MMWR Recomm Rep* 2006; **55**: 1-23
57. Jack BW, Atrash H, Coonrod DV, Moos MK, O'Donnell J, Johnson K. The clinical content of preconception care: an overview and preparation of this supplement. *Am J Obstet Gynecol* 2008; **199**: S266-279.
58. Dean SV, Imam AM, Lassi ZS, Zulfiqar A. Systematic Review of Preconception Risks and Interventions. Pakistan: Division of Women and Child Health, Aga Khan University 2013
59. Shawe J, Delbaere I, Ekstrand M et al. Preconception care policy, guidelines, recommendations and services across six European countries: Belgium (Flanders), Denmark, Italy, the Netherlands, Sweden and the United Kingdom. *Eur J Contracept Reprod Health Care* 2015; **20**: 77-87
60. Temel S, van Voorst SF, de Jong-Potjer LC et al. The Dutch national summit on preconception care: a summary of definitions, evidence and recommendations. *J Community Genet* 2015; **6**: 107-115
61. van der Pligt P, Willcox J, Hesketh KD et al. Systematic review of lifestyle interventions to limit postpartum weight retention: implications for future opportunities to prevent maternal overweight and obesity following childbirth. *Obesity reviews : an official journal of the International Association for the Study of Obesity* 2013; **14**: 792-805
62. Choi J, Fukuoka Y, Lee JH. The effects of physical activity and physical activity plus diet interventions on body weight in overweight or obese women who are pregnant or in postpartum: a systematic review and meta-analysis of randomized controlled trials. *Preventive medicine* 2013; **56**: 351-64.

63. Jarlenski MP, Bennett WL, Bleich SN, Barry CL, Stuart EA. Effects of breastfeeding on postpartum weight loss among U.S. women. *Preventive medicine* 2014; 69:146-50.
64. Lopez-Olmedo N, Hernandez-Cordero S, Neufeld LM et al. The Associations of Maternal Weight Change with Breastfeeding, Diet and Physical Activity During the Postpartum Period. *Maternal and child health journal* 2016; 20:270-80.
65. Neville CE, McKinley MC, Holmes VA, Spence D, Woodside JV. The relationship between breastfeeding and postpartum weight change--a systematic review and critical evaluation. *International journal of obesity* 2014; 38:577-90.
66. Lumley J, Watson L, Watson M, Bower C. Periconceptional supplementation with folate and/or multivitamins for preventing neural tube defects (Review). *Cochrane Database of Systematic Reviews*(2) 2002
67. Dean SV, Lassi ZS, Imam AM, Bhutta ZA. Preconception care: closing the gap in the continuum of care to accelerate improvements in maternal, newborn and child health. *Reprod Health* 2014; **11** Suppl 3: S1
68. van Uitert EM, Steegers - Theunissen RP. Influence of maternal folate status on human fetal growth parameters. *Molecular nutrition & food research* 2013; **57**: 582-595
69. Abell SK, Nankervis A, Khan KS, Teede HJ. Type 1 and Type 2 Diabetes Preconception and in Pregnancy: Health Impacts, Influence of Obesity and Lifestyle, and Principles of Management. *Seminars in reproductive medicine* 2016; **34**,: 110-120 Thieme Medical Publishers.
70. Shannon GD, Alberg C, Nacul L, Pashayan N. Preconception healthcare delivery at a population level: construction of public health models of preconception care. *Matern Child Health J* 2014; **18**: 1512-1531.
71. Stephenson J, Patel D, Barrett G et al. How do women prepare for pregnancy? Preconception experiences of women attending antenatal services and views of health professionals. *PLoS One* 2014; **9**: e103085.
72. Hall JA, Mann S, Lewis G, Stephenson J, Morroni C. Conceptual framework for integrating 'Pregnancy Planning and Prevention' (P3). *J Fam Plann Reprod Health Care* 2016; **42**: 75-76
73. Chief Medical Officer. (2014). From www.gov.uk/government/uploads/system/uploads/attachment_data/file/484383/cmo-report-2014.pdf
74. Levine R, Lloyd CB, Greene M, Grown C. Girls Count: A Global Investment & Action Agenda. Washington D.C., Center for Global Development 2009
75. Levine R, Temin M. Start With A Girl: A New Agenda for Global Health. Washington, D.C., Center for Global Development 2009

76. Todd AS, Street SJ, Ziviani J, Byrne NM, Hills AP. Overweight and obese adolescent girls: the importance of promoting sensible eating and activity behaviors from the start of the adolescent period. *Int J Environ Res Public Health* 2015; **12**: 2306-2329
77. Kimani-Murage EW, Kahn K, Pettifor JM, Tollman SM, Klipstein-Grobusch K, Norris SA. Predictors of adolescent weight status and central obesity in rural South Africa. *Public Health Nutr* 2011; **14**: 1114-1122.
78. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci* 2011; **6**: 42
79. Economos CD, Brownson RC, DeAngelis MA et al. What lessons have been learned from other attempts to guide social change? *Nutr Rev* 2001; **59**: S40-56; discussion S57-65.
80. Grace M, Woods-Townsend K, Byrne J et al. Science for health literacy: it's never been so important. *Education in Science* 2013; **252**: 16-17
81. Roberto CA, Swinburn AB, Hawkes C et al. Patchy progress on obesity prevention: emerging examples, entrenched barriers, and new thinking. *Lancet* 2015; **385**: 2400-2409
82. Draper CE, Micklesfield LK, Kahn K et al. Application of Intervention Mapping to develop a community-based health promotion pre-pregnancy intervention for adolescent girls in rural South Africa: Project Ntshembo (Hope). *BMC Public Health* 2014; **14 Suppl 2**: S5.
83. Barker M, Lawrence WT, Skinner TC et al. Constraints on food choices of women in the UK with lower educational attainment. *Public Health Nutr* 2008; **11**: 1229-1237
84. Hampson SE, Martin J, Jorgensen J, Barker M. A social marketing approach to improving the nutrition of low-income women and children: an initial focus group study. *Public Health Nutr* 2009; **12**: 1563-1568
85. Jarman M, Inskip HM, Ntani G, Cooper C, Baird J, Robinson SM, Barker ME. Influences on the diet quality of pre-school children: importance of maternal psychological characteristics. *Public Health Nutr* 2015; **18**: 2001-2010
86. Jarman M, Ogden J, Inskip H et al. "How do mothers manage their preschool children's eating habits and does this change as children grow older? A longitudinal analysis. *Appetite* 2015; **95**: 466-474
87. United Nations. The Global Strategy for Women's , Children's and Adolescents' Health (2016-2030) from <http://globalstrategy.everywomaneverychild.org/>
88. Kinsman J, Norris SA, Kahn K et al. A model for promoting physical activity among rural South African adolescent girls. *Glob Health Action* 2015; **8**: 28790
89. Bandura A. Exercise of human agency through collective efficacy. *Current Directions in Psychological Science* 2000; **9**(3): 75-78

90. Barker M, Baird J, Lawrence W et al. The Southampton Initiative for Health: a complex intervention to improve the diets and increase the physical activity levels of women from disadvantaged communities. *J Health Psychol* 2011; **16**: 178-191
91. Baird J, Jarman M, Lawrence W et al. The effect of a behaviour change intervention on the diets and physical activity levels of women attending Sure Start Children's Centres: results from a complex public health intervention. *BMJ Open* 2014; **4**: e005290.
92. Manandhar DS, Osrin D, Shrestha BP et al. Effect of a participatory intervention with women's groups on birth outcomes in Nepal: cluster-randomised controlled trial. *Lancet* 2004; **364**: 970-979
93. Prost A, Colbourn T, Seward N et al. Women's groups practising participatory learning and action to improve maternal and newborn health in low-resource settings: a systematic review and meta-analysis. *The Lancet* 2013; **381**(9879): 1736-1746.
94. Denktas S, Bonsel GJ, Van der Weg EJ et al. An urban perinatal health programme of strategies to improve perinatal health. *Matern Child Health J* 2012; **16**: 1553-1558
95. Denktas S, Poeran J, van Voorst SF et al. Design and outline of the Healthy Pregnancy 4 All study. *BMC Pregnancy Childbirth* 2014; **14**: 253.
96. Steegers EA, Barker ME, Steegers-Theunissen RP, Williams MA. Societal Valorization of New Knowledge to Improve Perinatal Health: Time to Act. *Paediatric and Perinatal Epidemiology* 2016; **30**: 201-4
97. Brand A, Walker DK, Hargreaves M, Rosenbach M. Intermediate outcomes, strategies, and challenges of eight healthy start projects. *Matern Child Health J* 2010; **14**(5): 654-665.
98. Salihu HM, Mbah AK, Jeffers D, Alio AP, Berry L. Healthy start program and feto-infant morbidity outcomes: evaluation of program effectiveness. *Matern Child Health J* 2009; **13**: 56-65.
99. Hanson MA, Bardsley A, De-Regil LM et al. The International Federation of Gynecology and Obstetrics (FIGO) recommendations on adolescent, preconception, and maternal nutrition: "Think Nutrition First". *Int J Gynaecol Obstet* 2015; **131** Suppl 4: S213-253

.
. .
.

