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Supporting Pregnant Women to Improve Their Diet and Physical Activity Behaviours

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Abstract

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A woman's diet quality and level of physical activity during pregnancy will influence both her own health and the lifelong health of her offspring. From the earliest stages of development, a baby's health and long-term risk of disease are programmed according to its mother's nutritional status and body composition, among other factors. One way of improving the health of the next generation is therefore to intervene during pregnancy, supporting women to improve their health behaviours, and give their offspring the best possible start.

Pregnancy is often viewed as a teachable moment when women are more motivated to improve their health for their babies' benefit. However, many pregnant women gain weight that exceeds guidelines and do not meet recommendations for physical activity, showing that more needs to be done to support women to make a change during pregnancy. It is clear from the literature that the factors that influence diet and physical activity in pregnancy are complex and wide-ranging, and many of these factors influence one another. For this reason, a complex adaptive system framework underpins this thesis with a particular focus on individual-level factors as these have not previously been conceptualised as a complex system. This work was undertaken to inform the development of future interventions to support women to improve their diet and physical activity behaviours in pregnancy.

First, questionnaire data were analysed to identify key factors associated with diet and physical activity in mothers of childbearing age. This analysis identified that social support, self-efficacy for healthy eating, perceived control, food involvement and positive outcome expectancies were associated with diet quality and that self-efficacy for physical activity was associated with women's level of physical activity.

The second study comprised a systematic review of behaviour change interventions in pregnancy that aimed to increase physical activity or improve diet quality, and that also aimed to improve at least one individual-level factor that may mediate or moderate intervention effectiveness. Nine studies were identified. Narrative synthesis of these studies showed that knowledge and planning were both amenable to change and associated with changes in behaviour.

Finally, a qualitative study that included interviews with recently pregnant women, and focus groups with pregnant women, was undertaken to gain a richer understanding of women's experiences in pregnancy and their engagement with available behaviour change support. Women's interest in improving their health behaviours, and their engagement with available sources of support, appeared to be closely linked to the extent to which they identified as healthy people. Thus, 'health identity' is a key concept that emerged from this research. Data from the qualitative work also showed that pregnancy-specific symptoms such as nausea make it difficult for some women to make a change, even if they intend to do so, and that women's interest in their own health is an important factor that affects their motivation to change.

The findings from these three studies have been incorporated into a complex adaptive systems model, which may be used to inform the development of future interventions to support pregnant women to improve their diet quality or increase their levels of physical activity.

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Research Thesis: Declaration of Authorship

Print name: Taylor Cydney Morris

Title of thesis: Supporting Pregnant Women to Improve their Diet and Physical Activity Behaviours

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. Parts of this work have been published. See **Appendix L.**

Signature: Date:

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Table of acronyms

ABM	Agent-based model
BMI	Body mass index
CAS	Complex adaptive system
CIHAHL	Cumulative Index of Nursing and Allied Health
CRD	Centre for Reviews and Dissemination
DAG	Directed acyclic graph
DALY	Disability adjusted life year
DOHaD	Developmental Origins of Health and Disease
FFQ	Food frequency questionnaire
FG	Focus group
GDM	Gestational diabetes mellitus
GIS	Geographic Information Systems
GPPAQ	General Practice Physical Activity Questionnaire
GCSE	General certificate of secondary education
GWG	Gestational weight gain
HCS	Healthy Conversation Skills
HEBSIM	Health Behaviours Simulation
IMD	Index of multiple deprivation
IOM	Institute of Medicine
ITT	Intention to treat
LGA	Large for gestational age
LSOA	Lower-layer Super Output Area
MeSH	Medical Subject Headings
MVPA	Moderate to vigorous physical activity
NCD	Non-communicable disease
ODD+D	Overview, Design concepts, Details + Decision-making
ONS	Office for National Statistics
PBB	Preparation for Birth and Beyond
PCA	Principal components analysis
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	Randomised controlled trial
SCM	Social cognitive model
SCT	Social Cognitive Theory
SES	Socioeconomic status
SIH	Southampton Initiative for Health
SMART(ER)	Specific, Measurable, Action-orientated, Realistic, Timed, (Evaluated, Reviewed)
SPRING	Southampton PRegnancy Intervention for the Next Generation
SSCC	Sure Start Children's Centre
SWS	Southampton Women's Survey
TPB	Theory of Planned Behaviour
UK	United Kingdom
UPBEAT	UK Pregnancies Better Eating and Activity Trial
US	United States
WHO	World Health Organization

Chapter 1 Maternal nutritional status and the health of the next generation

1.1 Non-communicable diseases

The global burden of non-communicable diseases (NCDs) and its increase over the last few decades is a well-recognised public health problem. Analysis of data from the 2010 Global Burden of Disease study found that a number of NCDs were among the top 15 causes for Disability Adjusted Life Years (DALYs).[1] Furthermore, many of the risk factors for NCDs with the highest number of attributable DALYs were preventable and included high blood pressure, tobacco smoking, poor diet, alcohol use and high body mass index (BMI).[1,2] In response to the global rise in NCDs, and the increase in morbidity and mortality attributable to these, the World Health Organization (WHO) has initiated the WHO Global Action Plan for the Prevention and Control of NCDs 2013-2020.[3] This action plan aims to achieve a 25% reduction in death from cardiovascular disease, cancer, diabetes and chronic respiratory disease by 2025, relative to rates in 2010. It is, therefore, clear that a key area of priority in public health is to reduce the incidence of NCDs through prevention strategies.

1.2 Health inequalities

Addressing the burden of disease from NCDs is especially important amongst the most disadvantaged populations as these people experience the worst health outcomes. Deprivation in the UK is usually expressed in terms of Index of Multiple Deprivation (IMD) where each Lower-layer Super Output Area (LSOA)[a] is assigned a rank based on seven domains of deprivation: income deprivation; employment deprivation; education, skills and training deprivation; health deprivation and disability; crime; barriers to housing and services; and living environment deprivation. These ranked LSOAs are then divided into ten equal groups so that an IMD of 10 represents a household that is among the 10% least deprived in England and 1 represents the 10% most deprived.[4] Throughout this thesis, the terms 'IMD,' 'home IMD' and 'deprivation decile' will be used to refer to this ranking system. For simplicity, quintiles are sometimes used rather than deciles so an IMD of 5 represents the 20% least deprived and 1 represents the 20% most deprived in England.

[a] A Lower layer Super Output Area contains approximately 1,500 residents or 650 households and there are 32,844 LSOAs in the UK.

The report entitled 'Fair Society, Healthy Lives,' widely known as the Marmot Review, examined the differences in health outcomes between social groups as well as the gradient that exists in health between the most well-off and the most deprived.[5] Based on 1999-2003 data, those living in the most deprived neighbourhoods in England died an average of seven years earlier than those in the least deprived areas. Furthermore, the difference in disability-free life years between these groups was 17 years.[5] More recent reports show little improvement as data from 2014-16 collected by the Office for National Statistics (ONS) showed a 10 year difference in males' life expectancy at birth and a 7.4 year difference for females between the most and least deprived.[6] The difference in disability-free life expectancy between the most deprived and the least deprived in England was 17.3 years for males and 17.2 years for females.[6] **Figure 1.1** shows these inequalities in health by deprivation decile,[6] and between regions with the best and worst life expectancies, according to data from the ONS.[7] Furthermore, there is some evidence to suggest that health outcomes for the most deprived are no longer improving as in March 2018, it was reported that for girls born in the most deprived areas in 2014-16, life expectancy had fallen slightly compared to deprived girls born in 2011-13.[8]

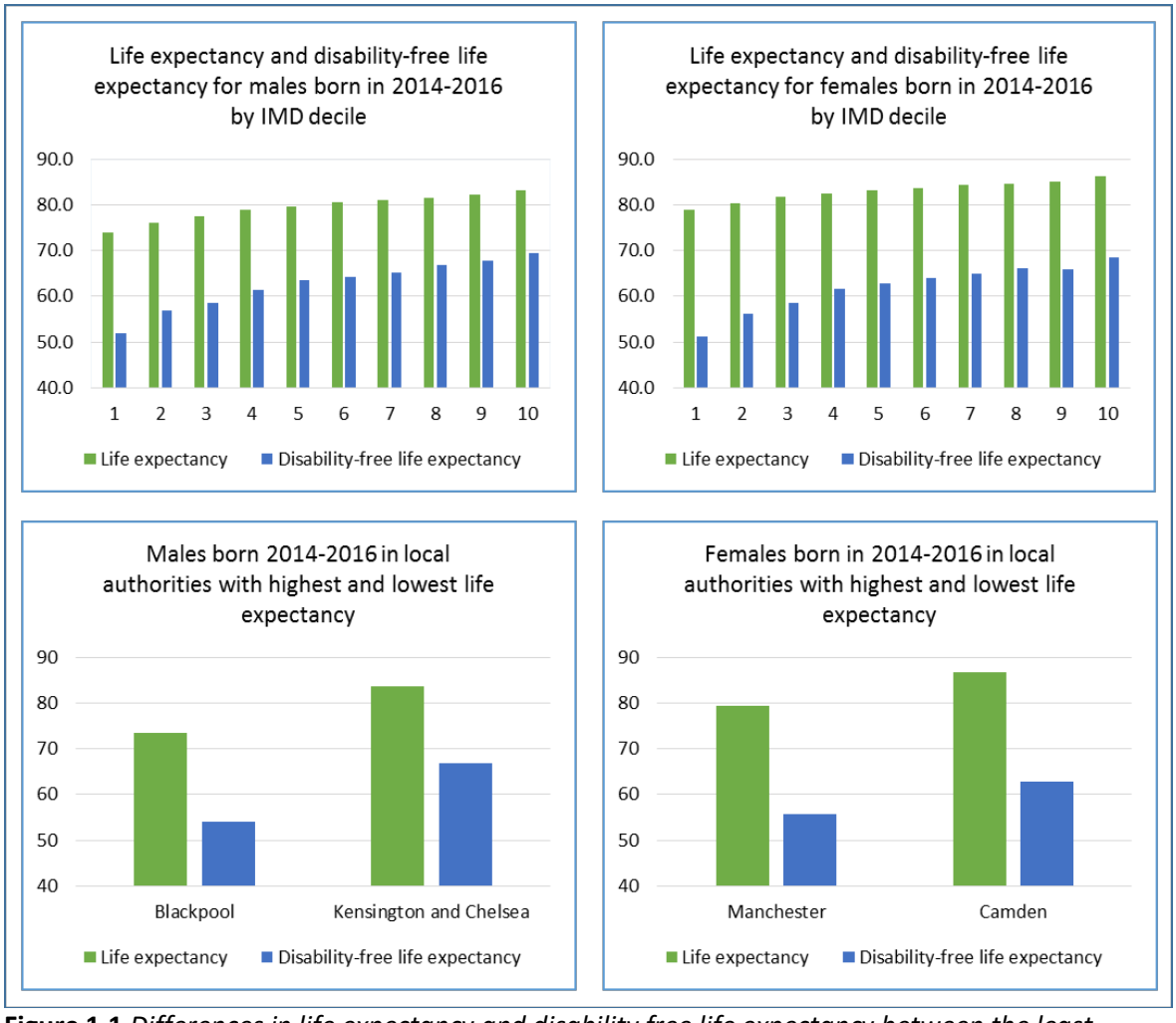


Figure 1.1 *Differences in life expectancy and disability free life expectancy between the least deprived and most deprived in England*[7]

It is widely accepted that socioeconomically disadvantaged people have shorter life expectancies and poorer health in general. These inequalities exist throughout the lifecourse, beginning before birth, as evidenced by the fact that more socioeconomically disadvantaged women have poorer pregnancy outcomes.[9-11] An analysis of birth records from 1989-1997 in the US state of Missouri found that women who lived in the 25% most deprived counties had a significantly higher risk of pre-term birth than women residing in the rest of the state.[10] Similarly, a study of air pollution and spina bifida in California found that this relationship was moderated by neighbourhood socioeconomic status (SES) such that the association was significant in the most deprived neighbourhoods, but not in the least deprived.[11] The Marmot Review[5] references the fact that inequalities begin before birth, and suggests that "one quarter of all deaths under the age of one would potentially be avoided if all births had the same level of risk as those to women with the lowest level of deprivation."(p.60)

1.3 Programming of NCDs and the Developmental Origins of Health and Disease (DOHaD)

1.3.1 Origins of the DOHaD hypothesis

Individuals' propensity to develop NCDs, and the inequalities in health outcomes between groups, originate before birth and are significantly influenced by conditions *in utero.* Indeed, a woman's nutritional status and body composition will have a life-long impact on her offspring; affecting a range of metabolic processes and influencing the probability of disorders such as type II diabetes and heart disease.[12-15] This paradigm, known as the Developmental Origins of Health and Disease (DOHaD) hypothesis, was first conceived when geographical data showed a strong relationship between mortality from ischaemic heart disease in 1968-78 and infant mortality between 1921 and '25.[16] Local authorities with higher levels of deprivation had higher infant mortality rates in the 1920s and higher mortality from ischaemic heart disease in the '60s and '70s.[16] The finding that ischaemic heart disease was more prevalent in deprived areas seemed paradoxical as, at the time, the rise in heart disease was thought to be caused primarily by a rise in prosperity. Given the correlation with infant mortality, it was proposed that propensity towards conditions such as heart disease and stroke actually originated much earlier in life than previously believed – possibly being traced back to conditions *in utero.*[16,17] This hypothesis was substantiated by observational studies conducted elsewhere, which similarly concluded that poor health in later life was correlated with early life influences.[16] Furthermore, maternal nutrition was thought to be a key factor and it was hypothesised that poor maternal nutrition, especially among the most deprived, impaired fetal development and led to poorer health in later life.[16-18] Development of

these hypotheses was largely influenced by the research of Barnet Woolf, who observed that stillbirth and neonatal mortality were dependent on levels of poverty in the area, and suggested that this relationship could be explained by poor maternal nutrition and lactation.[16,18]

Shortly after the publication of these early findings, data from the Hertfordshire Cohort Study[19] were analysed and results supported the hypothesis that early development influenced health in later life. Barker *et al.* and Osmond *et al.* showed a significant correlation between low birth weight and death from coronary heart disease in both men and women.[20,21] Given that infant mortality in the 1920s was usually associated with low birth weight, and that low birth weight itself was also associated with cardiovascular disease, findings appeared to suggest that prenatal factors (as opposed to factors operating in infancy) led to the permanent changes in physiology that predisposed individuals to disease in later life.[17] Contemporary and subsequent analyses of cohort data replicated these findings, showing significant associations between low birth weight and cardiovascular disease, as well as between low birth weight and risk factors for disease such as impaired glucose tolerance leading to type II diabetes.[22-29] In all of these studies, though, the link between prenatal factors and disease in later life was not explicit because low birth weight was only a proxy for prenatal influences.

The most compelling evidence in support of the DOHaD hypothesis has come from studies that directly linked maternal nutritional status or body composition with long-term outcomes in offspring.[13,30-34] An extreme example is seen in data from cohorts of people conceived or born during a famine. In the Netherlands in 1944-45, there was a severe famine as a result of war. At its worst, between December and April, adults were restricted to between 400 and 800 calories per day[35] and data from the cohort of babies born around this time provide unique insight into the effects of prenatal undernutrition on development and health. A number of developmental effects at birth were observed, such as smaller size of those exposed to famine in mid- or late gestation and larger size of those exposed in early gestation.[35] With regard to adult disease, those exposed to famine in mid- or late gestation had reduced glucose tolerance; the effect of which was larger than the apparent effect of famine on birth weight. The authors reasoned that immediate adaptations to prevent low birth weight had had a detrimental long-term impact.[35] The deleterious effect of malnutrition was most pronounced in those who were born as 'thin' babies to low weight mothers, and especially those who went on to become obese as adults, as these people had the highest glucose concentrations in a 2-hour glucose tolerance test.[36]

Crises such as famine and war provide pronounced evidence that the fetal environment causes permanent changes that impact on a person's lifelong health. In a less dramatic example, the Motherwell cohort study provides further insight. Here, the offspring of mothers who were

advised to eat one pound of red meat per day and avoid carbohydrate-rich foods during pregnancy had significantly higher blood pressure at age 27 to 30 years than their counterparts whose mothers ate a more balanced diet.[37] Furthermore, the offspring of mothers with the most unbalanced diets (highest in meat and fish and lowest in carbohydrates) showed significantly higher cortisol secretion in stressful situations.[38] There have been many other studies that have found similar associations between maternal nutritional status and infant outcomes, but evidence in support of the DOHaD hypothesis is not limited to nutrition.

Maternal body composition, which includes BMI and gestational weight gain (GWG), is also important. Many studies have found that body composition has a significant effect on offspring health in the long term. For example, a cohort study in Jerusalem examined these effects at 32 years of age and found that both high pre-pregnancy BMI and excessive GWG were associated with adverse outcomes. Specifically, when comparing the highest BMI quartile with the lowest, pre-pregnancy BMI was positively associated with offspring BMI, waist circumference and triglycerides. GWG was also positively associated with offspring BMI at age 32 years.[39] Data from 13,345 adults from the Helsinki Birth Cohort showed that maternal BMI was positively correlated with early death, cancer, stroke and especially cardiovascular disease and type II diabetes.[40] Another cohort study in Amsterdam showed that maternal overweight was associated with LGA and preterm birth and the association was greater amongst ethnic minority populations.[41] Maternal overweight and excessive GWG are known risk factors for gestational diabetes mellitus (GDM),[42] and elevated blood glucose during pregnancy will have detrimental effects on fetal development and long-term health as increased glucose crossing the placenta leads to greater insulin release and increased adipogenesis during development.[43,44] Moreover, this effect does not appear to be limited to cases of GDM or very high levels of blood glucose; rather, a linear relationship has been observed between maternal glucose and neonatal adiposity.[45]

In Southampton, UK, the Southampton Women's Survey (SWS) has shown that maternal diet and body composition influence not only birth outcomes, but also offspring body composition in childhood. For example, GWG was significantly positively associated with birth weight and excessive weight gain in pregnancy was associated with greater fat mass at birth and at and six years of age.[46] In the same cohort, glycaemic index and glycaemic load in early pregnancy (11 weeks) were significantly positively associated with offspring adiposity at ages four years and six years, but not at birth.[47] These findings lend support to the idea that maternal diet and body composition influence offspring health and further data collection and analysis from this cohort will provide further insights.

1.3.2 Developmental plasticity and programming of disease

Since the initial publications describing the association between early development and later health in the late 20th century, significant advances have been made in understanding the relationships between prenatal environment, fetal development and health throughout the lifecourse. It is theorised that the developmental plasticity of a fetus, while generally evolutionarily advantageous, predisposes individuals to NCDs when the intrauterine environment is sub-optimal or does not match the environment in which offspring live after birth. Plasticity has been defined as a process "by which organisms, in response to cues such as nutrition or hormones, adapt their phenotype to environment." (p.6)[48] From an evolutionary perspective, this process should result (and historically has resulted) in successive generations that are all best suited to their specific environments and therefore able to survive and reproduce. These changes are sometimes referred to as predictive adaptive responses, which are specifically adaptations that allow the person to reach reproductive age rather than being immediately beneficial.[34] In some cases, though, the cues given to a fetus by its mother do not accurately represent the environment in which a person will live. This mismatch can be seen in migrant populations where fetal development has established metabolic pathways prepared for low nutrition, but adults live in an environment of excess and the offspring are thus predisposed to become obese or develop type II diabetes.[44,49] The effects of maternal undernutrition and the associated adverse offspring outcomes have been studied extensively, as low birth weight has long been a proxy for inadequate fetal development and the mismatch hypothesis provides a good explanation for the insulin resistance and predisposition to NCDs that follow.[14,34,43,50] Still, it is not only the offspring of undernourished mothers who go on to develop these conditions, as they are widespread in developed countries like the UK. Rather, fetal programming occurs in every pregnancy.

The phenomenon whereby a fetus is 'programmed' to store energy and eventually develop metabolic diseases is not limited to populations where food is scarce, but rather it exists across all humans. Gluckman and Hanson[44] posit that early humans would have gained an evolutionary edge from underestimating the nutritional environment *in utero*, as those who stored more energy in times of scarcity would probably have survived and reproduced more successfully. Furthermore, fetal growth needs to be tightly controlled in humans to ensure passage through the birth canal and it is likely that maternal mechanisms to limit growth have evolved to act in all pregnancies. These mechanisms, described collectively as 'maternal constraint,' may work by limiting nutrients to the fetus in late pregnancy, which will always lead to some degree of mismatch.[44,51]

All of this suggests that there are multiple processes that have evolved with humans and led to a propensity to store excess energy, and this is particularly pronounced in cases where women have unbalanced or insufficient diets during pregnancy. In the modern age of excess, these mechanisms no longer confer an advantage, but there are no evolutionary forces at play that would lead to a reversal. Therefore, it is necessary to understand how maternal nutritional status and body composition affect offspring health, and how best to intervene to optimise fetal development.

1.3.3 Epigenetic changes

The molecular mechanisms that lead to the plasticity described above are complex and collectively termed 'epigenetics.' This refers to a number of systems by which gene expression is regulated, allowing for a range of possible phenotypes to result from a fixed genotype.[49] There are multiple processes by which gene expression can be regulated, but the most well-known and widely studied is methylation of specific sites on the genome where a cytosine-guanine dinucleotide is situated in a 5'-3' orientation, known as a CpG site.[49,52] Broadly, CpGs are usually located in the promoter region of a gene; the non-coding section upstream of a coding region where transcription factors bind to initiate expression of that gene.[53] When a methyl group binds to this site, RNA transcriptase and necessary transcription factors are unable to bind to initiate gene transcription, preventing gene expression. This process is represented in **Figure 1.2**. There are a number of other epigenetic mechanisms such as histone modification that also interrupt transcription in different ways, and all of these result in modified gene expression.[49]

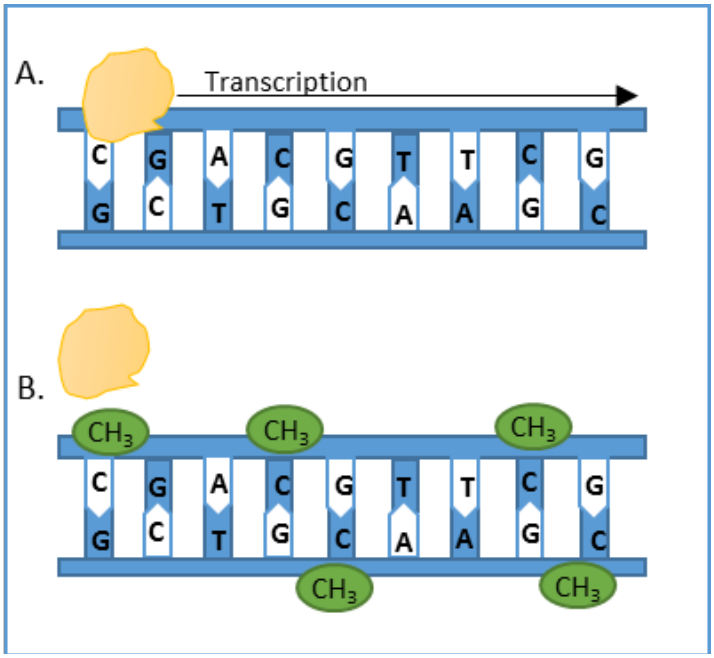


Figure 1.2 *Methylation of cytosine at CpG sites prevents transcription*
A: Transcription factors bind to DNA and initiate transcription.
B: Transcription factors cannot bind to methylated CpG sites

Development is dependent on these mechanisms from the earliest stages and it has long been understood that certain genes must be activated and suppressed at different points in embryonic and fetal development. For example, inactivation of a large proportion of genes in blastocyst cells allows for differentiation into specific cell types and female embryos must only contain a single active X chromosome, meaning the other must be inactivated.[54] These are just two examples of the myriad of normal and necessary epigenetic processes that take place during development, and where any of these goes wrong, diseases or abnormalities can result.

As research has progressed, it has become increasingly clear that epigenetic processes are sensitive to environmental cues. To return to the example of the Dutch famine (**Section 1.3.1**), a follow-up study of 60 members of this cohort investigated the epigenetic changes effected by famine during the periconceptional period, so only those conceived during the famine were included in this analysis. The authors chose to study the insulin-like growth factor II (IGF2) gene as it is a well-characterised epigenetically regulated locus that is important for development.[55] Results showed reduced methylation at the promoter region of this locus in the study population compared with their same-sex siblings, supporting the hypothesis that undernutrition during the earliest stages of gestation resulted in epigenetic changes that were still seen at age 60 years.[55] It is worth noting that the famine ended before these participants were born, and adequate nutrition during late gestation into infancy was obviously not sufficient to reverse these changes in line with the pathways that had been established in their siblings. Similarly, a study of 34 members from the Motherwell cohort found epigenetic links between unbalanced maternal diet, neonatal adiposity, and adiposity and blood pressure in adulthood. Methylation at the glucocorticoid receptor (GR) gene was positively associated with adiposity and blood pressure in adulthood and methylation at a promoter region of this gene (GR-1F) was particularly increased in offspring of mothers who had the most unbalanced diets, characterised by very high intake of meat and low intake of carbohydrates. [56] Glucocorticoids comprise a wide range of steroid hormones that affect physiological systems including inflammation, metabolism, stress response and various homeostatic pathways.[57,58] Methylation of promoter regions of other gene loci was similarly associated with both adiposity at birth and adiposity and blood pressure in adulthood.[56] These data showed that epigenetic changes persist throughout the lifecourse, and that maternal nutrition is a factor in this process that programmes metabolic pathways.

1.4 Maternal obesity and pregnancy outcomes in the UK

For most of human history, maternal undernutrition has been the primary cause for concern with regard to fetal development, but in recent years, maternal over-nutrition and excessive GWG have become more common around the world.[59] As is the trend with the general population, the prevalence of maternal obesity is rapidly increasing in the UK.[60] Maternal obesity in the UK is associated with a number of poor outcomes, including increased risk of stillbirth, babies being born large for gestational age (LGA) and increased odds of being admitted to a neonatal unit.[61] It is not yet clear whether the number of babies born LGA is increasing as high birthweight has only been routinely recorded since 2009.[62] However, the rise in maternal obesity across the country suggests that associated outcomes (both immediate and long-term) will also become more frequent. These poor health outcomes are not uniform across the country, but rather significant inequalities exist, as pregnant women living in the most deprived areas are more likely than the rest of the population to be obese.[60]

Appropriate GWG was defined by the American Institute of Medicine (IOM) in 2009,[63] and the guidelines are summarised in **Table 1.1**. There is currently a considerable amount of research into GWG and observational studies have found that many women exceed the IOM guidelines.[64] A recent meta-analysis found that of 1,309,136 pregnancies, 23% of women gained weight below Institute of Medicine guidelines and 47% gained weight above the guidelines. Both insufficient and excessive weight gain were associated with adverse birth outcomes including small for gestational age, preterm birth, LGA and caesarean delivery.[65] Unfortunately, there are no official guidelines for GWG in the UK, and weight is usually only measured once during pregnancy,[66] so national trends are not currently known.

Table 1.1 *Institute of Medicine recommendations for gestational weight gain*[63]

Pre-pregnancy weight status (BMI)	Recommended gestational weight gain
Underweight (<18.5)	28-40 lbs.
Normal weight (18.5-24.9)	25-35 lbs.
Overweight (25.0-29.9)	15-25 lbs.
Obese (≥30.0)	11-20 lbs.

1.5 Factors that influence health behaviours

Health behaviours such as diet and physical activity have an obvious influence on nutritional status and body composition during pregnancy and, like pregnancy outcomes, health behaviours differ between the more disadvantaged and the better-off. A Dutch study demonstrated this in an analysis of ethnic differences and GWG where there were significant differences in weight gain between ethnic groups, and socioeconomic factors and lifestyle explained up to 45% of the variation.[67] Another cross-sectional analysis of data from the Netherlands found that pregnant women of lower educational attainment were significantly more likely to smoke, be exposed to smoke, not attend antenatal classes and not take folic acid supplements than women of higher educational attainment.[68] Similarly, data from the SWS showed that level of education was the most important factor in predicting the diet quality of women of childbearing age in Southampton, UK.[69] There are a number of potential explanations for these discrepancies in health, including environmental, interpersonal and individual factors, as represented in social-ecological models of health. Dahlgren and Whitehead[70] first described, diagrammatically, the levels of influence on individual health in 1991 (**Figure 1.3**), and their model has since been adapted for many purposes.[71-73] This model is a useful starting point to visualise the various factors that may influence diet and physical activity, and subsequently nutritional status and body composition, and some of these factors are discussed below in relation to diet and physical activity.

Figure 1.3 *Dahlgren and Whitehead 1991*[70]

A range of environmental factors have been shown to influence health behaviours as well as health outcomes. These include availability of healthy and unhealthy foods and accessibility of exercise facilities. For example, the 'healthfulness' of the supermarket environment, determined by such factors as price, shelf placement and healthier alternatives, has been linked to dietary quality in women.[74] Similarly, some environmental factors such as accessibility to exercise facilities and neighbourhood safety have been associated with levels of physical activity in adults.[75,76] Environmental changes, often effected through policy, may be successful in improving health behaviours in the UK and elsewhere. A Cochrane review of plain cigarette packaging suggested that implementing this measure supported a reduction in smoking behaviour[77] and a review of evidence has found that alcohol minimum unit pricing is likely to reduce alcohol consumption.[78] It is probable, then, that an effective intervention to support improved diet and physical activity will require environmental changes as well.

In addition to the physical environment, social norms[79-81] are an important environmental factor that can influence people's beliefs, attitudes and health behaviours. Pregnancy and parenthood are rife with social norms and stigma, which vary by culture and have a strong influence on behaviour. For example, Eastern cultures observe a number of traditions related to pregnancy and childbirth, like the Chinese tradition of *zuo yuezi*, or 'Sitting the Month.' This is a period of post-partum convalescence where the woman is discouraged from leaving the house, bathing, working, or doing a number of other things, and is encouraged to eat specific foods that are thought to aid recovery and promote long-term health for both the woman and her baby.[82] Studies in both Australia[83] and Scotland[84] have found that *zuo yuezi* is not only an important tradition in China, but that it remains important for Chinese immigrants to Western countries. Cultural practices and beliefs like this may necessitate culturally tailored interventions or approaches, but the influence of social norms is not limited to migrant populations.

In the UK, smoking during pregnancy is a good example of a behaviour that carries considerable stigma. Currently, the majority of smokers give up smoking for the duration of their pregnancies,[85] and for some women the primary motivation is to achieve social desirability.[86] However, these norms and the related behaviour can vary by context. A qualitative study conducted in East Surrey, UK showed that women from more deprived neighbourhoods were more tolerant of smoking during pregnancy, regardless of their own smoking status.[86] An analysis of data on pregnant women in California found that living in a predominantly working-class area significantly increased the odds of smoking in pregnancy compared to living in an area that the authors designated as middle-class, regardless of individual SES.[87] While little research has been done on the associations between cultural norms and diet quality or levels of physical activity in pregnancy, the examples above show that environmental and cultural influences must be

considered when conceptualising the factors that influence health behaviours in pregnancy and how these behaviours may be improved.

Closely related to social norms, interpersonal relationships and social networks can influence behaviour, and have even been associated with changes in BMI.[88] Social support is an interpersonal factor that has been associated with diet and physical activity beliefs and behaviours in pregnant women[89] and other adults.[90,91] Social networks represent the relationships and interactions between people, and can also be very influential. Recently, health researchers have used computer simulation models, such as agent-based models (ABMs), to better understand the influence of social contact and environmental factors on population-level BMI changes over time.[88] Such models have been used to examine the potential effects of obesity prevention interventions, taking social influences and individual differences into account,[92] and have shown that social expectation can independently predict weight change in some groups.[88]

At an individual level, there are many factors that are associated with health and health behaviours. Self-efficacy,[93-95] perceived control,[96,97] social support,[90,95,98,99] outcome expectancies,[93,100] food involvement,[101,102] educational attainment[74,100,103] and health literacy/knowledge[104-106] have all been associated with diet and/or physical activity behaviours in adults. As these factors will be considered and discussed throughout this thesis, they are briefly described below.

Self-efficacy is a key concept in Social Cognitive Theory (described in **Section 2.1**),[107-109] and can be general or behaviour-specific. General self-efficacy refers to a person's belief that they can carry out any given behaviour[107] while self-efficacy for a healthy diet, for example, would focus on a woman's belief that she could maintain a healthy diet, implying that she had the knowledge and skills to do so.[110] Increasing diet-specific self-efficacy has been associated with an increase in fruit and vegetable consumption.[95]

Perceived control is closely related to self-efficacy and represents a person's belief that they have control over their life.[107,108] A study conducted in Southampton found that perceived control mediated the significant association between self-efficacy and diet quality in women of lower educational attainment. There were no significant associations among women of high educational attainment, suggesting that there may have been other protective factors in the environments of highly educated women, such as better access to healthy food.[100]

Social support represents the degree to which a person feels supported and encouraged to engage in healthy behaviours. Social support for healthy eating refers to how much or how often a person feels that their friends, partner, children, or others encourage them to purchase and eat

healthy foods.[99,111] In a study that considered a number of home influences on fruit and vegetable consumption, including home availability and outcome expectancies, social support was the most significant predictor.[99]

Outcome expectancies are the consequences that a person expects from engaging in a certain behaviour.[112] For example, they may expect that regular physical activity will help them lose weight, or conversely they may believe that eating highly processed foods will not have any discernible effect on their health. Positive outcome expectancies have been shown to predict quality of diet in women of lower, but not higher, educational attainment.[100]

Food involvement refers to the priority that people give food in their lives, and includes things like enjoying cooking, interest in trying new foods, and placing importance on setting the table for a meal. Food involvement has been associated with educational attainment and also with consumption of fruit and vegetables.[100,101] It has been suggested that women of lower educational attainment perceive more barriers to trying new foods, such as budgetary constraints and less support from partners and children to eat a varied diet. This in turn may reduce the enjoyment women get from cooking and eating, and their interest in these activities.[101]

Finally, a few studies have found that nutrition knowledge may be an important predictor of diet quality in some groups of people. For example, an American study found an interaction between educational attainment and nutrition knowledge such that the association between education and diet quality was only significant amongst adults with high levels of nutrition knowledge.[104] Similarly, an Australian study of new mothers found that nutrition knowledge mediated the association between SES and diet quality.[105]

It is clear from the social-ecological model presented above, as well as findings from extensive research, that none of these factors acts on its own, but rather multiple factors at different levels interact in influencing behaviour. For example, women of lower educational attainment are more susceptible to the influences of the supermarket environment[74] and affordability of exercise facilities is particularly important in determining physical activity levels in ethnic minorities and people of lower SES.[76] In order to improve population health and address the increasing prevalence of NCDs, it is necessary to intervene at multiple levels, and at different points in the lifecourse. One group that may be an ideal target for public health interventions is pregnant women because improving a woman's health during pregnancy will not only benefit her, but has the potential to also improve the health of her offspring. An adapted social-ecological model of some of the factors hypothesised to influence women's health behaviours, and ultimately nutritional status and body composition, is shown in **Figure 1.4**.

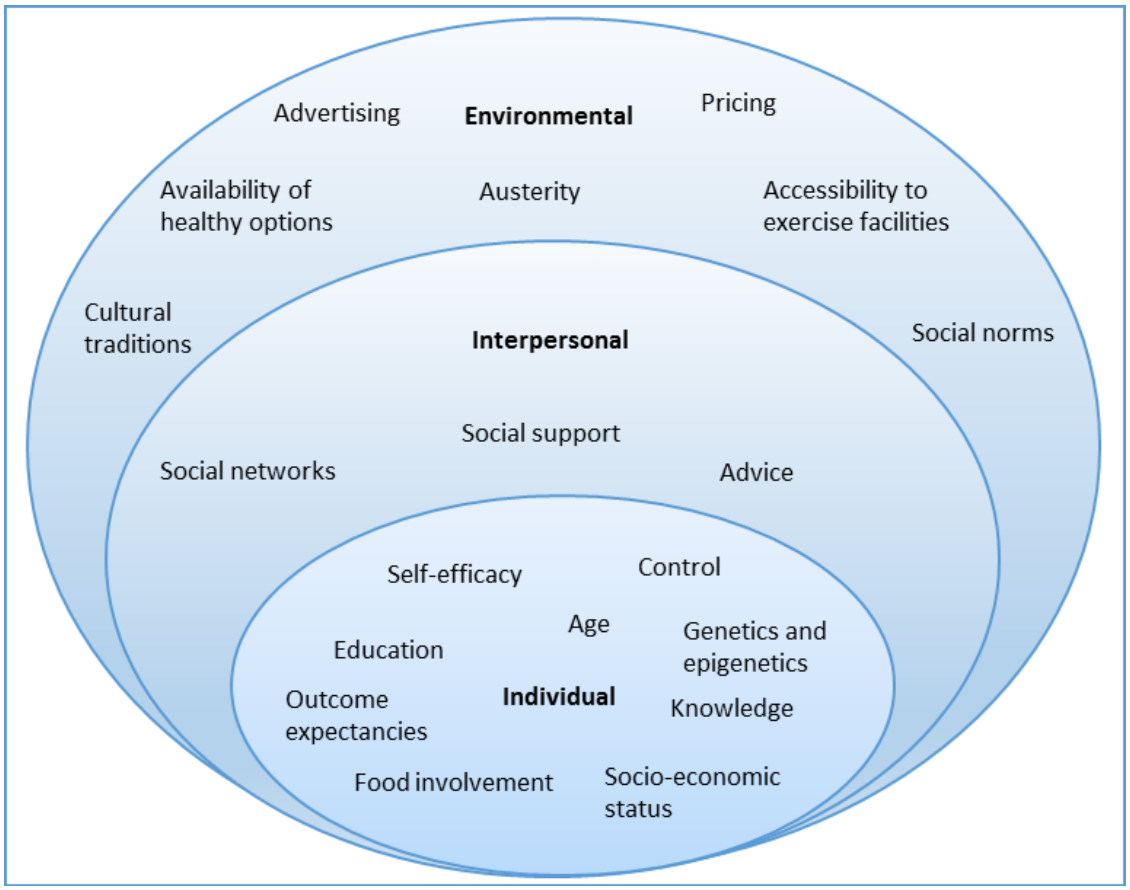


Figure 1.4 *Social ecological model of factors that may influence maternal nutritional status or body composition*

1.6 Behaviour change interventions in pregnancy

Pregnancy is clearly an important point in the lifecourse for improving health behaviours and it is thought to be a teachable moment because many women are motivated to improve their health for the benefit of their unborn child.[113,114] This idea is supported by the fact that most smokers quit smoking when they fall pregnant as they know it is detrimental to the fetus to continue to smoke.[85,113] Similarly, it is common for pregnant women to give up alcohol, or significantly reduce their intake, for the duration of their pregnancy and while breastfeeding. Still, these are short-term changes in behaviour that typically last only for the duration of pregnancy,[115] and most smokers will return to smoking within nine months of giving birth.[85] This suggests that the motivation for adopting healthier behaviours with regard to smoking and alcohol often comes solely from factors related to being pregnant. Indeed, qualitative research into smoking cessation during pregnancy has shown that social pressure associated with smoking while pregnant discourages women from smoking, as does concern for the wellbeing of the fetus.[116]

While changes in behaviours that are known to cause harm such as smoking and alcohol consumption are common, and apparently motivated by pregnancy, changes to less straightforward behaviours like eating a healthy diet and being physically active are less common and more difficult to achieve through intervention. Analysis of FFQ data from the SWS found that very few women significantly changed their dietary behaviours during pregnancy.[117,118] A recent systematic review of observational studies found that physical activity levels tend to decrease markedly during pregnancy and often do not return to pre-pregnancy levels after birth.[119] These data suggest that pregnancy is not necessarily an impetus for women to improve their diets or to be sufficiently physically active, and current trends show that effective interventions are required to support improved health behaviours in pregnancy.

Public Health England report that half of women of childbearing age are overweight or obese, with about 19% of women falling into the obese category (BMI ≥30kg/m^2).[120] Furthermore, significant inequalities exist as a large UK-based cohort study found that greater risk of obesity in pregnancy was associated with greater levels of deprivation, unemployment and Black ethnicity.[121] While many interventions have been developed, trialled and implemented, levels of obesity among women continue to rise, suggesting that further research and intervention development is vital. This project, therefore, aims to identify which factors are associated with diet and physical activity behaviours in pregnant women, and which of these are amenable to change through intervention. Finally, a framework for developing an effective intervention that aims to improve diet and physical activity behaviours during pregnancy will be developed through this research.

1.7 Southampton context

The data presented in this thesis were collected primarily from women in Southampton, UK and the surrounding area. Southampton is a relatively deprived city with 15.4% of the population, and 19.7% of children, living in low-income households (defined as income less than 60% of the median household income[122]).[123] The most recent joint strategic needs assessment for Southampton highlights the need to 'improve economic wellbeing' in order to narrow health inequalities, which are also a considerable problem in Southampton.[124] Indeed, there is a difference in life expectancy between the most deprived decile and the least deprived decile of 8.4 years for men and 5.7 years for women.[125]

Some measures of mortality suggest relatively poor health in Southampton as the under 75 mortality rate from preventable causes is significantly higher than the national average and life expectancy at birth for males is significantly lower than the national average at 78.5 years.[123,126] Regarding health behaviours, diet and physical activity are of some concern. For most measures of physical activity, Southampton is similar to the England average, but figures for adults achieving less than 30 minutes per week and for adolescents exceeding 7 hours of sedentary time per day are significantly worse.[125] Similarly, the proportion of people who reported eating at least five portions of fruit and vegetables per day was significantly lower than the England average.[125]

1.8 Research questions

This thesis aims to address three research questions. Questions 1 and 2 have been introduced in this chapter, and Question 3 will be introduced in Chapter 2.

1. How can we support women during pregnancy to improve their diet and physical activity behaviours?

2. What modifiable factors are associated with diet and physical activity, and changes to these behaviours, in pregnancy?

3. How can the factors that influence diet and physical activity in pregnancy be conceptualised as a complex adaptive system?

Chapter 2 Taking a complex adaptive systems approach

2.1 Introduction

It is good practice to base behaviour change intervention design in theory.[127,128] This helps to guide research and aids interpretation of its findings, so an appropriate framework for this project should be selected ahead of collecting or analysing data. There are many options to consider as experts in the field of behaviour change have developed a number of theories of behaviour, which all have their proponents as well as their critics. Social cognitive models (SCMs) are very common in behaviour change literature, and popular examples of SCMs are the Health Belief Model,[129] the Theory of Planned Behaviour (TPB),[130] the Transtheoretical model,[131,132] and Social Cognitive Theory (SCT). [107,108]

2.2 Common models of behaviour

As its name suggests, the Health Belief Model focuses on attitudes and beliefs as predictors of behaviour (**Figure 2.1**).[129,133] In particular, it posits that people make decisions to avoid disease based on perceived susceptibility to the disease, perceived seriousness of the disease and perceived benefits of/barriers to taking action to avoid the disease.[133] While there is evidence that health beliefs and outcome expectancies do play a role in influencing behaviour,[96,100] this model suggests that health behaviours are determined by individual cognitive factors.

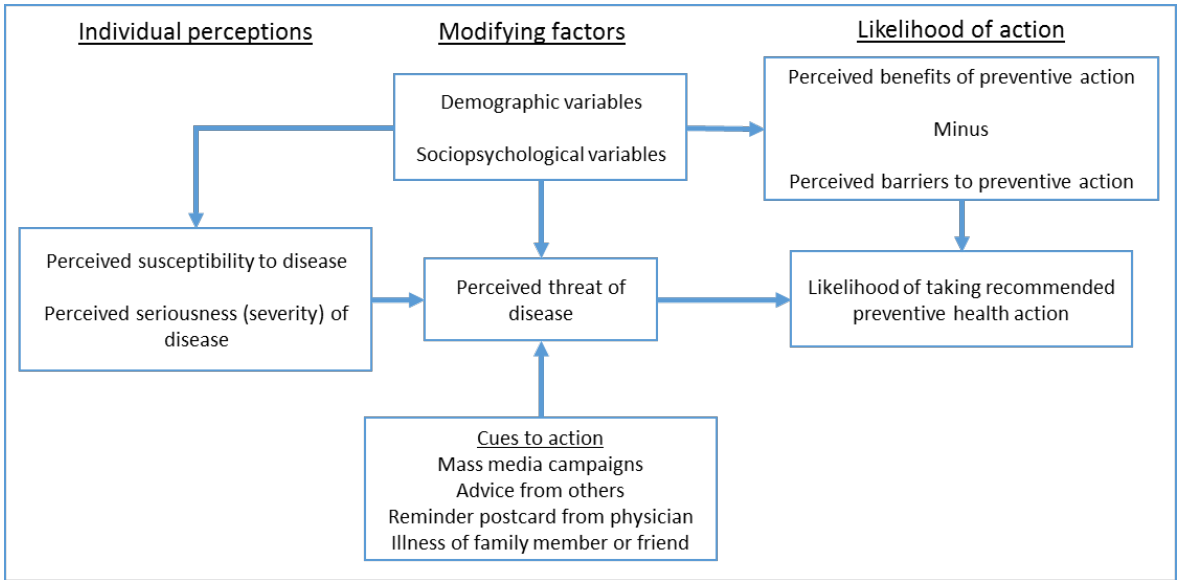


Figure 2.1 *Health Belief Model*[129,133]

TPB (**Figure 2.2**) is more comprehensive and presents human behaviour as actions that begin as intentions and are, to some extent, planned.[134] In this model, attitudes, subjective norms and perceived control influence intention, which in turn leads to action and these factors are seen as influencing each other.[134] While TPB takes into account important psychological constructs and their interaction, it is still focused only on factors acting on an individual level and its proponents concede that it is limited to actions that could be performed without any practical barriers, such as time, money, skill and resources.[134]

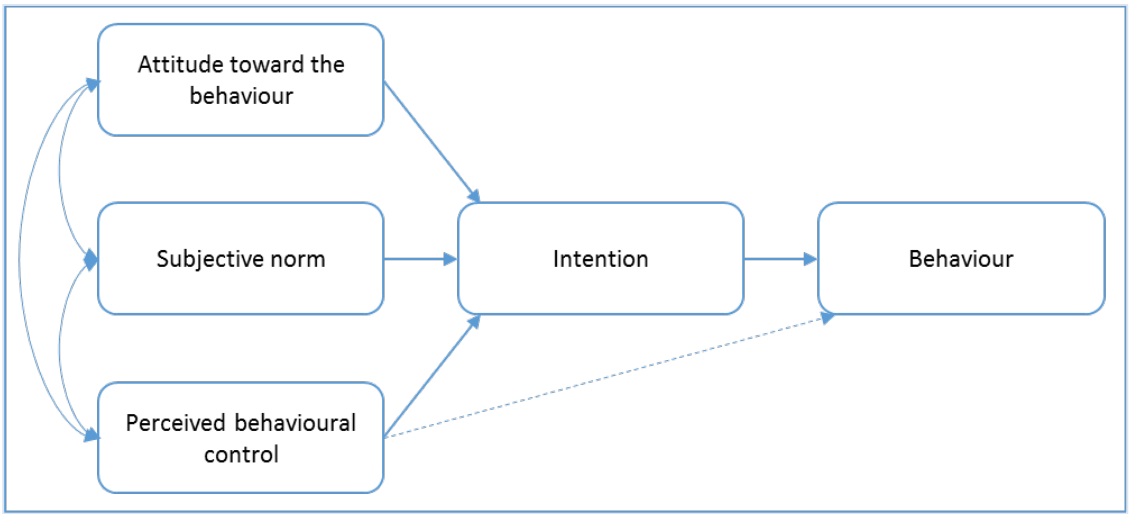


Figure 2.2 *Theory of Planned Behaviour*[134]

The Transtheoretical model (**Figure 2.3**) was developed as an integration of multiple models of behaviour, and includes a temporal element.[132] That is, behaviour change is a process that happens over time, and in various distinct stages: precontemplation; contemplation; preparation; action; maintenance; and termination, and ten processes of change were originally proposed to support progression through these stages.[132] These are called: consciousness raising; dramatic relief; self-revelation; environmental re-evaluation; self-liberation; local liberation; counterconditioning; stimulus control; contingency management; and helping relationships.[132] Clearly, a range of psychological factors is included in this model, and many behaviour change interventions use Transtheoretical model principles to support participants to progress to the next stage of change.[91,135,136] Still, there is considerable emphasis on cognitive processes required to move from one stage to the next.

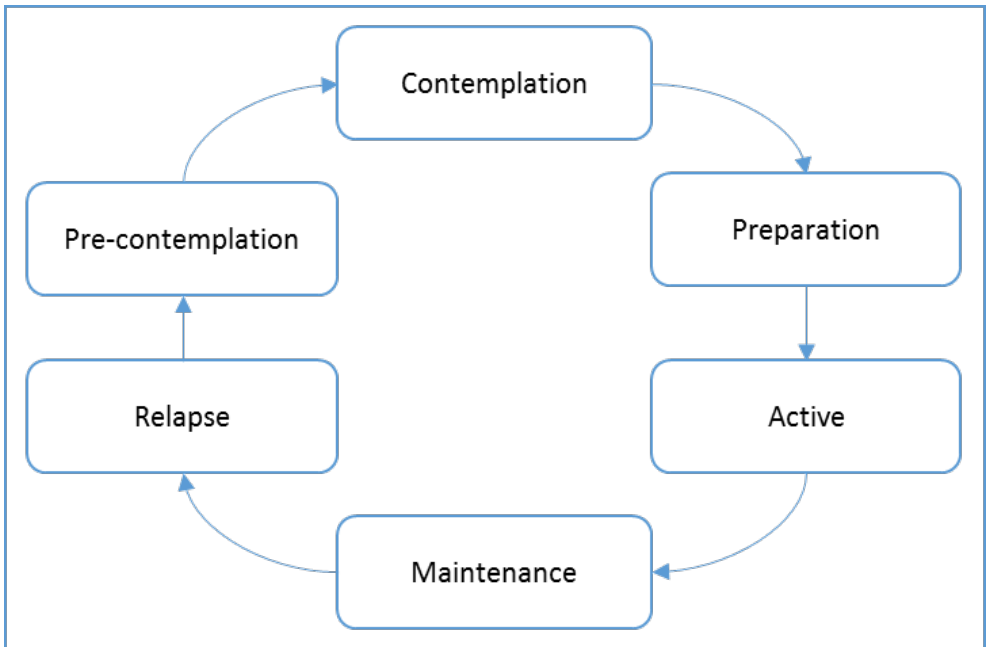


Figure 2.3 *Transtheoretical model*[132]

SCT is a theory of social learning that describes a 'model of triadic reciprocal causation'[109] where environmental factors, personal factors, and behaviour all influence one-another as well as future behaviour (**Figure 2.4**). SCT suggests that behaviours are learned through observing others, but the theory also highlights the range of factors that influence the adoption and performance of a given behaviour. Depending on the behaviour, the 'Person' field of the model may include individual factors such as attitudes, cognitions, knowledge and beliefs. The 'Environment' field may include social relationships and norms, food availability or neighbourhood safety. The 'Behaviour' field may include practice and mastery of a given behaviour, enjoyment that results from the behaviour or the experience of trying the behaviour. While all of these fields are modelled to have reciprocal influences, it is important to note that the relative importance of each part of the model will be context-specific.[109,137] Central to SCT is self-efficacy, which influences, and is influenced by, the overall functioning of the system.[109,137]

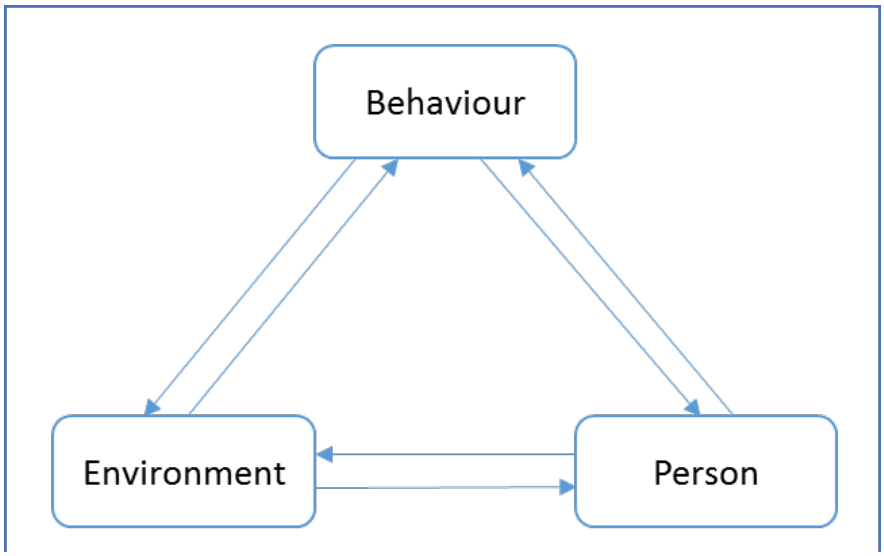


Figure 2.4 *Triadic influence on behaviour proposed in SCT*[109,137]

Despite their popularity, there are a number of recognised limitations associated with SCMs.[127,138,139] Firstly, SCMs often focus on cognitions as determinants of behaviour, rather than other psychological and environmental factors,[127] and trials have shown SCMs to be relatively poor predictors of behaviour.[138,140] This may be the case because: widely-used measures of cognition are inadequate;[141] cognitive constructs are poorly defined;[139] and most importantly, cognitive constructs alone do not determine behaviour.[127,138] Some experts even argue that, while useful on a pragmatic level, there is little support for their validity in explaining behaviour or behaviour change.[138,139] A particularly critical review of SCMs found that studies purporting to test their application to a particular behaviour were flawed because most study findings:

> 'did not strongly support the models being used[…]But such data are not used to reject the model in question. Instead explanations are offered which function as caveats perpetuating the belief that the models have been verified. All data can be used to indicate the strength of a social cognition model, but it would appear that no data can be collected to show that it was wrong.'[139]

This is not the only review to criticise the use of SCMs in behaviour change interventions, and another likened these models to old clothes that no longer fit, arguing for the introduction of models that address the complexity of factors that influence health behaviours. (p.425)[138]

Indeed, a major limitation of most behaviour change models is that they fail to represent the range of factors that interact to influence people's behaviours, and the complexity with which this may occur.[142,143] Many interventions have been developed according to traditional behaviour change models like SCMs, and some public health campaigns, such as the drive to reduce smoking prevalence, have been successful.[144] However, diet and physical activity are very complex behaviours and interventions designed to improve these often fail to yield significant or lasting changes.[127] Furthermore, despite the public health focus on obesity, the ever-increasing

prevalence of obesity-related NCDs necessitates improvements in both our understanding of the mechanisms that govern health behaviours and our competence to elicit meaningful changes through effective intervention. The social ecological model[70] described in **Section 0** does more to take environmental and other factors in consideration, and is often referenced in developing public health models and interventions.[72,145] However, this model does not sufficiently take into account feedback loops, adaptive responses, or changes over time.

In order to improve understanding, it may be appropriate to model the processes of behaviour change in a different way and examine the evidence through an alternate lens. This should begin with removing the assumptions that processes of behaviour change are deterministic, and that behaviour change is a wholly cognitive process. As summarised by Resnicow and Page,[146] traditional frameworks assume that outcomes are proportional to inputs and that change is governed by rational and cognitive processes. They further point out that behaviour is generally conceptualised as a combination of knowledge, attitude, belief, self-efficacy and intention and that the relationships between these factors, as well as the behaviours they dictate, follow linear functions.[142] While such frameworks are easy to understand and use, it is clear that human behaviour is more complex than most of these theories would suggest. For example, the overwhelming frequency with which people fail to maintain their new year's resolutions shows that having good intentions and setting goals are often not sufficient to support sustained change. Equally, a person who has failed to give up smoking many times may finally succeed at kicking the habit for good, citing a kind of epiphany that was either brought on by a change in circumstances or an inexplicable internal shift. Such changes show that 1) behaviour change is often unpredictable, 2) outputs are not always proportional to inputs and 3) mechanisms of behaviour change may be very different between individuals. These characteristics suggest that human behaviour is better understood within the parameters of a complex adaptive system, which have the following properties: 1) they are governed by nonlinear mechanisms; 2) they can be unpredictable or appear random and 3) they are adaptive and self-organising such that a change in one factor may result in responsive changes in other factors.[142,143,147-149]

A model of behaviour that was developed relatively recently, and views the factors that influence behaviour change as a dynamic system, is the 'capability, opportunity, motivation and behaviour' (COM-B) model (**Figure 2.5**).[150] Here, 'capability' includes both physical and psychological factors, 'opportunity' includes environmental and social factors and 'motivation' includes both reflective and automatic processes.[150] This model of behaviour proposes that all of the determinants of behaviour or behaviour change fit into one of the 'COM' categories and that all areas of the system interact with each other. As a result, feedback loops and interaction between different parts of the system can yield amplified or dampened effects over time. Of course, the exact

components that make up a given system are context- and behaviour-specific, as is their relative importance.[150] While it has been noted that some factors associated with behaviour change do not readily fit into one of the COM-B categories, but rather impact on behaviour through influencing components within these categories,[151] it is nevertheless widely-used for designing and evaluating behaviour change interventions.[152-154]

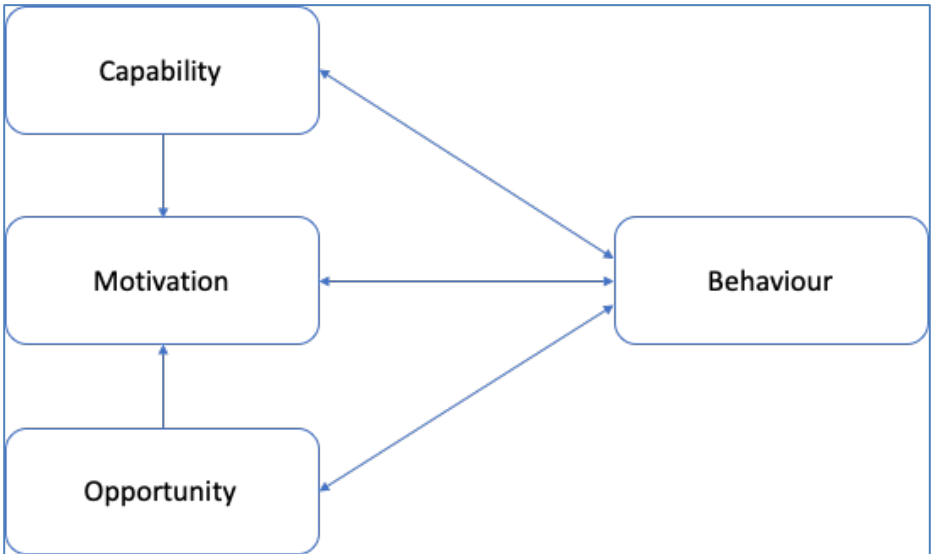


Figure 2.5 *The COM-B model*[150]

The interactions between model components, and the inclusion of both individual-level and environmental factors, mean that the COM-B model is likely more representative of the processes that drive behaviour change and therefore more useful for designing effective interventions. The benefits of this approach are clear, but there may be additional benefit to expanding on the principles of interaction within a dynamic system in order to gain a more granular understanding of: which factors influence health behaviours in pregnancy; which of these are modifiable; how this system may vary between individuals and how it could change over time. An in-depth approach, which may be seen to complement the principles of the COM-B model, can be found in the study of complex adaptive systems (CAS).

2.3 Complex adaptive systems

The study of CAS is a field whose roots are firmly planted in the study of physics, making strict application of its concepts and terminology best suited to natural systems in the physical world, including biological and chemical processes. However, computer models[155] as well as observational studies of populations and individuals,[142,147,156] have shown that human behaviour can be well-understood using the same paradigm. Therefore, the system of factors that interact and guide a person's behaviour will be conceptualised here as a CAS with the implicit concession that abstract concepts such as social support and perceived control do not physically interact in the same way that, for example, neurons interact to form memories. Conceptualising behaviour, and behaviour change, as the result of a CAS can provide useful insights for developing interventions that aim to improve health behaviours. Further, given the focus on improving health behaviours during pregnancy, it will be necessary to consider which new factors are introduced by pregnancy or motherhood, and how these factors may influence the system as a whole. This chapter will describe the key characteristics of a CAS and consider how these could apply to health behaviours during pregnancy.

2.3.1 Complex adaptive systems are comprised of nonlinear functions

Complex adaptive systems are comprised of nonlinear functions; a characteristic that makes outputs difficult or impossible to predict. William Miller studied the unpredictable nature of human behaviour extensively and suggested that some people experience a kind of 'epiphany' of a mystical nature and describe it as happening *to* them, often when they reach a certain point of desperation. Others have a more cognitive 'epiphany' or 'ah-ha!' moment, which is perhaps more likely to result from external influences such as psychotherapy.[157] This view of behaviour change is not particularly helpful because we cannot reasonably hope to instigate epiphany though a public health intervention. However, an alternative view of such a dramatic change in behaviour can be more logically described as the result of bifurcation; a property of a CAS that will be discussed below.

Aside from being difficult to predict or identify, describing a system as 'nonlinear' is an insufficient definition as it only means that the system is not linear. In algebra, a polynomial expression is described as 'nonlinear,' providing the simplest interpretation of this term. In a polynomial function, each input has a single predictable output, but a change in input does not result in a proportional or consistent change in the output. A simple example is the Yerkes-Dodson law; a popular model that shows that performance follows a bell-shaped curve in relation to stress when performing a difficult task (**Figure 2.6**).[158] In other words, an increase in input (arousal) leads to an

increase in output (performance) up to a point, after which performance begins to decrease. Furthermore, a change in input does not lead to a proportional (linear) change in output at any point along the curve.

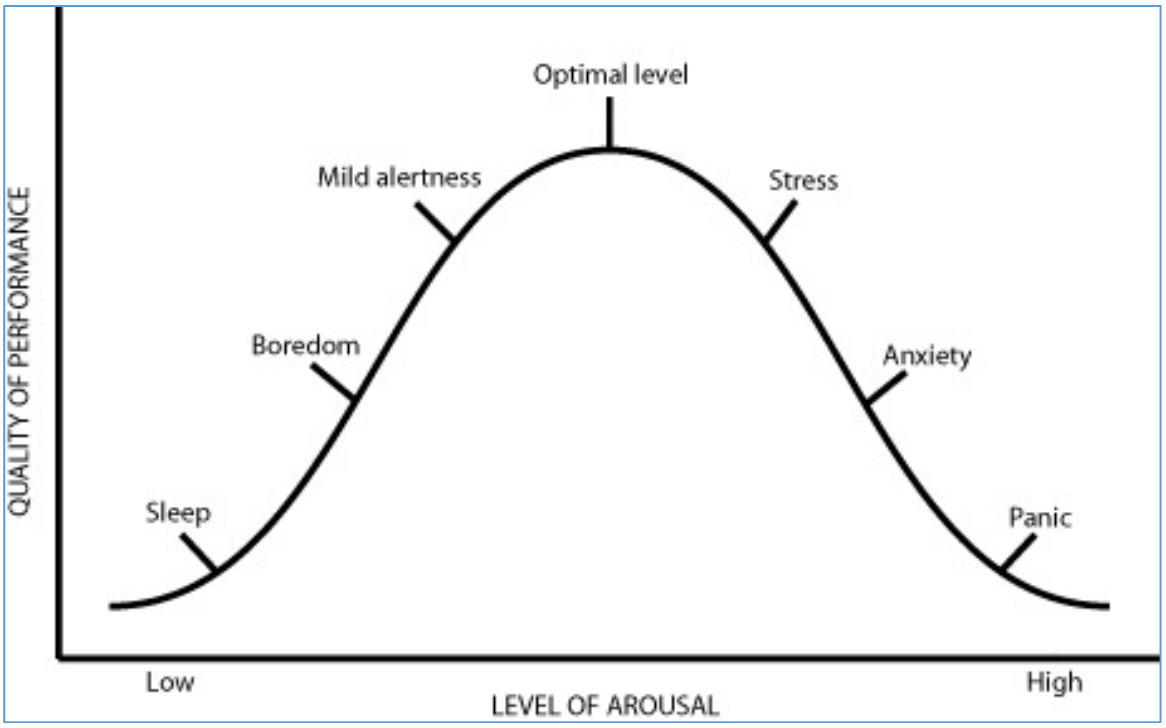


Figure 2.6 *Yerkes-Dodson Law proposes a nonlinear relationship between level of arousal and quality of performance*

However, in the study of system dynamics, 'nonlinear' does not usually refer to this simple algebraic definition. Rather, a nonlinear function is a function that is not additive and "due to feedback or multiplicative effects between the components, the whole becomes something greater than the mere sum of its individual parts." (pg.1)[159] Such systems, while following a set of deterministic rules, can result in irregular and even unpredictable outputs over time. Furthermore, due to their nonlinearity, outcomes can be amplified or dampened in relation to inputs, making intervention effects difficult to forecast.[143,159]

A common way to represent the properties of nonlinear functions is through the concept of bifurcation. In the literature, an apparently simple nonlinear function, which describes the change in the number of organisms in a population over time, is used:

$x_{t+1}=(r)\,(x_t)\,(1-x_t)$
x_t = population at time t
r = growth rate

x_{t+1} is expressed as a value between 0 (extinction) and 1 (maximum capacity). Therefore, a population at any given time is dependent on both the growth rate and the population at the previous time point.[143,159,160] As shown in **Figure 2.7**, for each growth rate (r) between 0 and 3.57, the function settles on a specific value or set of possible values for x after a number of iterations.

For growth rates nearer to zero, the system will settle on a single value. As growth rate increases, the system will oscillate between two values, then four, eight, and so on. The points at which the diagram splits are called bifurcation points. After the threshold growth rate of 3.57, the function enters into a state of non-repetitive oscillation that will eventually reach an infinite number of possible population values.[159] There are mathematical explanations for the bifurcation points and threshold value of 3.57, but a detailed exploration of all of the features of this function is not necessary here. The key point to understand is that, while the system appears to descend into chaos due to its unpredictability, it is produced from a simple deterministic, but nonlinear, mathematical equation.

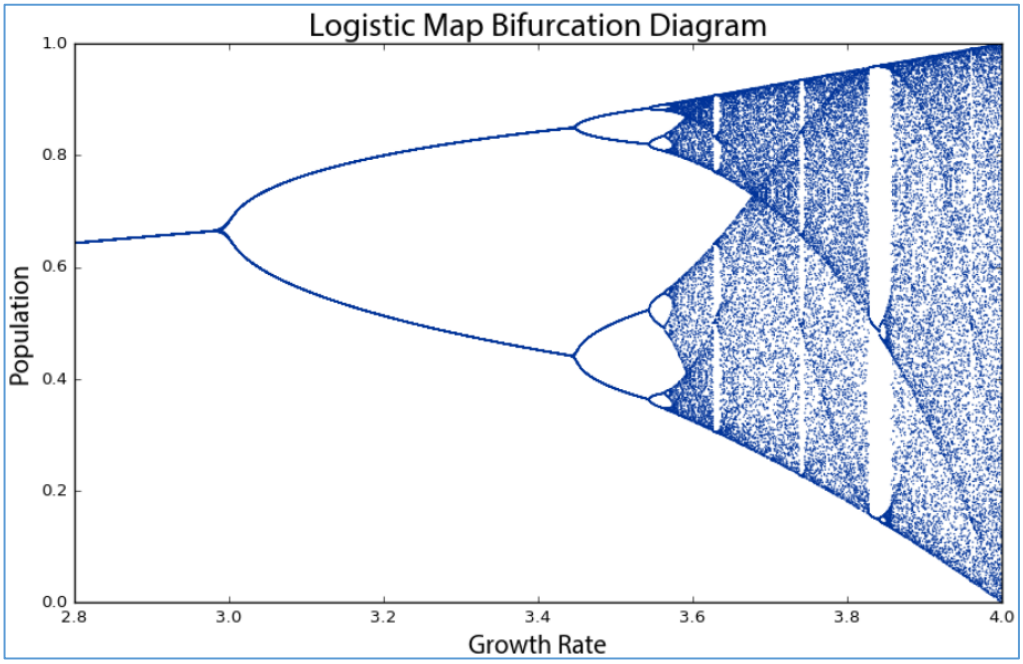


Figure 2.7 *Bifurcation diagram taken from Boeing (2016)* [159]

If this concept can be applied to behaviour change, it suggests that the influence of certain inputs is less predictable than one may initially assume. For example, people may respond to social pressure in this way, such that a person's likelihood to quit smoking with increasing levels of social pressure settles on a predictable value over time, but once a certain threshold is passed, there is a split in the path where a person will either become much more or much less likely to quit. Qualitative research into smoking during pregnancy supports this idea in that some women reported quitting due to the increased social pressure brought about by pregnancy while others said that they were driven to keep smoking to cope with the higher levels of judgement and stress associated with smoking whilst pregnant.[116] Psychologists recognised the potential of bifurcation points in the 1990s, with some experts suggesting that amplifying a person's discomfort could drive them to a state of instability where they would either embark upon an increasingly destructive path or eschew maladaptive behaviours in favour of healthier ones, placing them on

the beneficial path. The role of the therapist here would be to support the person to adopt better behaviours rather than harmful ones.[147]

There are some other unique properties of nonlinear functions, but while interesting, they do not merit further exploration for the purposes of this thesis. The intention of the explanation above is to show that the functions underlying a CAS are deterministic, but can be difficult or impossible to solve because inputs are not necessarily proportional to outputs and outputs sometimes appear chaotic. However, because these functions do follow rules, the range of possible outputs, or general trends, can be modelled and predicted. In terms of an intervention, this means that, while we may not be able to estimate the result of an intervention for any one person, we can estimate a population average, or the range of likely outcomes in the population. Additionally, identifying bifurcation points, such as might be reached during pregnancy, could improve the effectiveness of behaviour change interventions by taking advantage of the readiness to change that may occur at such points.

2.3.2 Complex adaptive systems are sensitive to past behaviours

The example of population change given in **Section 2.3.1** shows that the mechanisms underlying a CAS are sensitive to previous patterns. This is an intuitive concept with regard to behaviour as people normally behave according to habits they have formed. Beyond this, studies of complex systems have shown that pathways can be very sensitive to initial trajectories, resulting in dramatically different end points from starting points that are almost indistinguishable. Edward Lorenz is credited with making this observation first, when he studied weather patterns using computer models and found that shortening an input value from six significant figures to three resulted in a considerably different output over time (**Figure 2.8**).[142,159] Chaos theory, including the concept of the 'butterfly effect' emerged from this first observation and subsequent studies have found chaotic systems in the weather, population change, fluid dynamics, epidemiology and the stock market.[142,146] This characteristic is a direct result of the nature of nonlinear functions underlying a CAS. Because these functions undergo repeated iterations, initially small differences in input are amplified or dampened over time, leading to dramatically different outputs in the long run.[147]

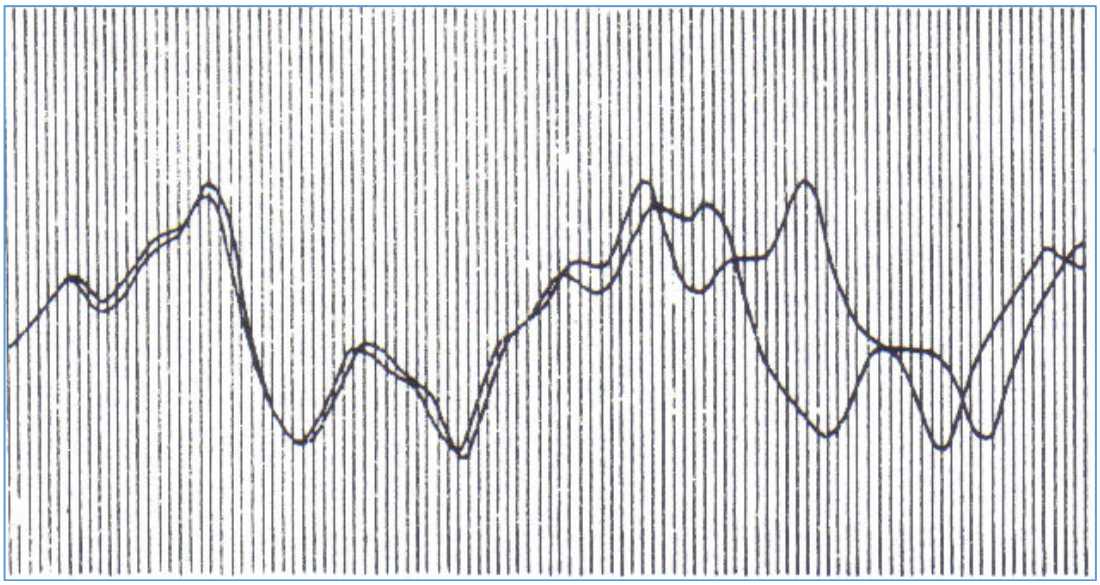


Figure 2.8 *Different weather patterns resulted from similar input values (0.506127 versus 0.506) in a computer simulation*[142,159]

Looking at behaviour change from this perspective, one could logically conclude that multiple people who appear to all have the same value for a given psychological characteristic may in fact respond differently to an intervention.[146] For instance, people who are assigned the same score on a self-efficacy questionnaire, or are considered to be at the same stage of change in the Transtheoretical model,[161] will not all respond equally well to an intervention designed to support weight loss. Resnicow and Page have come to this conclusion, stating that 'initial conditions could include knowledge level, current attitudes and mood states…genetics and a myriad of other intrapsychic and environmental states and traits. The potential permutations in initial conditions are virtually infinite, which suggests that the potential pathways to change are too.'(p. 1383)[142] In pregnancy, this could mean that a woman who has exercised regularly for years may find it easier to remain active than a woman who has only recently started to exercise.

While chaotic systems are not predictable *per se,* they do follow recurrent patterns. Therefore, if some patterns and circumstances under which change is likely to occur can be identified, behaviour change could be supported more effectively, with the understanding that not all individuals will respond in the same way.[142]

2.3.3 Complex adaptive systems are self-organising

Rather than assuming that behaviour is driven by a single individual, social or environmental factor, it is more appropriate to view behaviour as being driven by a CAS that is not governed by any centralised source of control. This is, in fact, another feature that arises from the nonlinear functions underlying complex systems. Here, individual factors or functions interact with other factors in close proximity, driving the system towards a stable or organised state.[147] Some

common examples of this are the way ants behave in a colony or the way a flock of birds travels. No single organism is controlling the behaviour of the group as a whole, but rather each member of the group follows a set of rules in response to the ones around it and this leads to coordinated movement. The overall shape of the flock of birds or the health of an ant colony can be seen as an 'emergent property,' or an outcome of a system that cannot be explained or predicted by any one actor within the system. We can see similar patterns in human societies through cultural preferences or changing fashion trends. These systems are often described as being on the 'edge of chaos' because they settle on an ideal state between adaptability and stability.[147]

If the factors involved in health behaviours make up a CAS that is, to some extent, self-organising, then it is likely that a change in one factor will lead to adaptive changes in other factors with the potential to effect a net change in the system overall. Such dynamics are caused by a network of positive feedback (reinforcing) and negative feedback (balancing) loops whose interdependence can be very complex and difficult to map. However, trends may be observable and allow us to identify key 'levers' for activating change as well as the patterns in which the levers might be pulled.[147] To present a simple example, it could be theorised that self-efficacy and weight loss are part of a positive feedback loop (where a change in one leads the other to change in the same direction) but that self-efficacy and smoking are part of a negative feedback loop (where a change in one leads the other to change in the opposite direction). Here, improving self-efficacy would be an effective means of promoting two healthy behaviours, but relapsing on one health behaviour may lead to relapse in the other and move the whole system towards poorer health behaviours. In this case, it may be advisable to implement a multicomponent intervention that aims to improve self-efficacy, support smoking cessation and promote a healthy diet. This is a simplistic illustration, and it should be understood that there is a myriad of factors at play in this system, which would all be constantly responding and adapting, but a few key factors may be identified through trends in the population, informing the development of an effective intervention. Similarly, pregnancy may introduce new factors to the system such as nausea,[162] cravings and anxiety,[163] which could interact with a woman's beliefs about the importance of a healthy diet. Changes in eating habits might 'emerge' from these interactions to find an acceptable balance between avoiding foods that exacerbate nausea (even if they are healthy), indulging in cravings and ensuring adequate nutrition.

2.3.4 Complex adaptive systems interact with their environments

Of course, none of the factors involved with behaviour exists in a vacuum. Rather, they make up a system that is constantly receiving input from its environment and from other systems. In biological systems, the advantage of a CAS is to allow the organism to respond to its environment

and optimise fitness. Viruses use adaptive mechanisms to evade the immune systems of their hosts, constantly evolving in response to their environment.[143] Furthermore, a system may respond actively in an attempt to modify its environment to be more suitable.[147] There are many examples of such dynamics including predator-prey relationships and arms races between groups.[147] As described in **Section 1.5**, myriad environmental and social factors influence health behaviours and social inequalities mean that individuals have different environments with which they will interact in different ways.

The recent rise in veganism can be viewed as an example of a system interacting with its environment as a recent survey found that 3.5 million people in the UK are now vegan; up from approximately 540,000 in 2016.[164,165] While individual vegans cite different reasons for changing their diets, including animal welfare, environmental concerns and health beliefs,[166] the combined demand for plant-based options has effected changes to the wider environment. Retailers have developed more vegan-friendly products and innovative food items are constantly being introduced.[165] These changes to the food environment may be one factor influencing the rise in veganism. In addition, it has been suggested that social media has been effective at popularising vegan culture, as have vegan celebrities.[164,165] While these findings are based on observational and opportunistic survey data, and may not be representative of the whole UK population, this apparent phenomenon provides a simple example of how a group of people can interact with their environment and effect a positive feedback loop. As veganism continues to gain popularity, the culture and environment in the UK are becoming increasingly accommodating of these requirements, which in turn may encourage even more people to become vegan. Hence, the relationship between individuals and the wider environment can be seen as forming a positive feedback loop where both individuals and environmental factors are constantly influencing each other.

Many of the scenarios described in this chapter show that complex systems respond to inputs from their environments, and this can reasonably be applied to human behaviour and the complex systems that govern these processes. Therefore, it is likely that environmental inputs need to be considered when examining the complex system of factors influencing women's lifestyles during pregnancy.

2.4 Complex adaptive systems in public health

Although a number of commentaries have been written in recent years about the need to apply complex systems frameworks to public health problems,[142,146,167,168] there only a few examples of this being done in practice. One of the earliest examples of applying a complex systems framework to obesity is found in the 'Foresight Report.'[169] This report, which synthesised data and expertise from a range of subject areas, showed that a broad range of factors were interacting in complex ways and leading to the rise in obesity in the UK. The included domains were physiology, diet and physical activity behaviours, food production, social psychology and individual psychology, and they were all described as interacting and forming feedback loops as discussed in **Section 2.3.3.** The resulting systems map (**Figure 2.9**) is often referenced as an example of an extremely complicated model, but serves to portray the complexity of public health issues like the obesity epidemic. The authors of the Foresight report suggested some key intervention points and highlighted the importance of intervening in multiple domains across the system to make a meaningful change. They also pointed out the need for further evidence to inform the assumptions made in the map, the strength of association between the various factors, and the potential efficacy of different types of intervention.

Since the publication of the Foresight Report in 2007,[169] subsequent obesity strategies such as 'Healthy Weight, Healthy Lives'[170] and then 'Healthy Lives, Healthy People,'[171] have referenced Foresight and the idea that multiple factors were involved in propagating the rise in obesity, and that work across sectors would be necessary to reverse this trend. The explicit recognition of the wider determinants of health, and the drive to take a multi-faceted, cross-sector approach to tackling obesity have certainly been productive outcomes of the Foresight report, but the complex systems principles related to feedback loops and key intervention levers have not been taken forward by more recent policy documents or other government reports. Rather, policy makers still tend to focus on implementing specific single-component initiatives.[172]

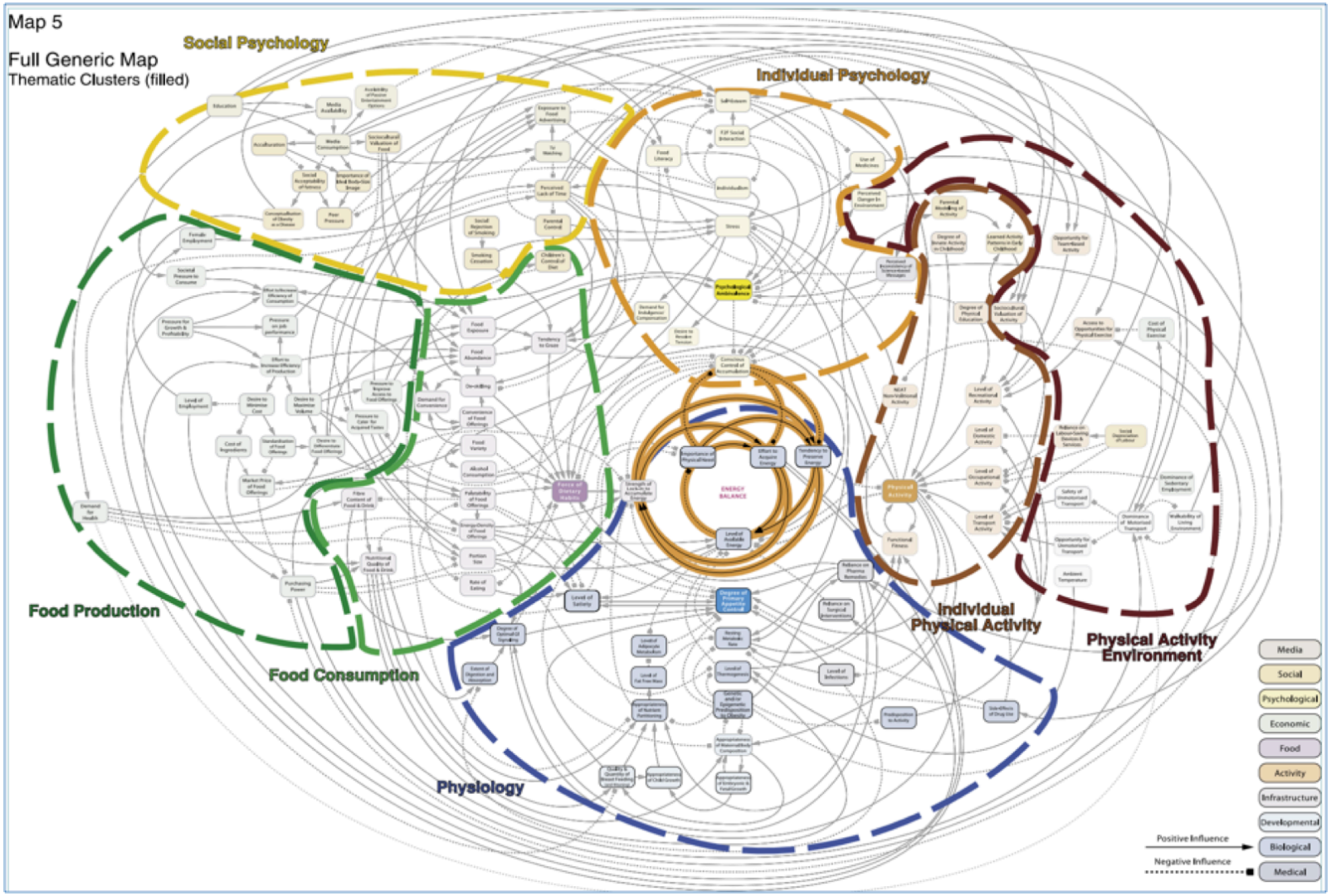


Figure 2.9 *Systems map from the Foresight Report of the factors that influence obesity*[169]

The industry levy on sugar-sweetened soft drinks[173] (sugar tax) that came into effect in April, 2018 is an example of a single-component intervention, but its effects will be complex and impact on multiple points within a system.[174] The analysis plan for this intervention is unique in that a team of researchers are analysing its effects on multiple outcomes, taking a complex systems approach.[174,175] This team have developed a system map in collaboration with a range of experts (**Figure 2.10**), and are collecting and analysing data on government actions, food industry actions, consumer behaviour, public discourse and actions within other sectors such as healthcare. Data collected over a four-year period and analysed through four different work packages will provide a rich understanding of how a fiscal intervention can cause changes in a complex system and have economic, social and health impacts in both the short and long term.[174,175]

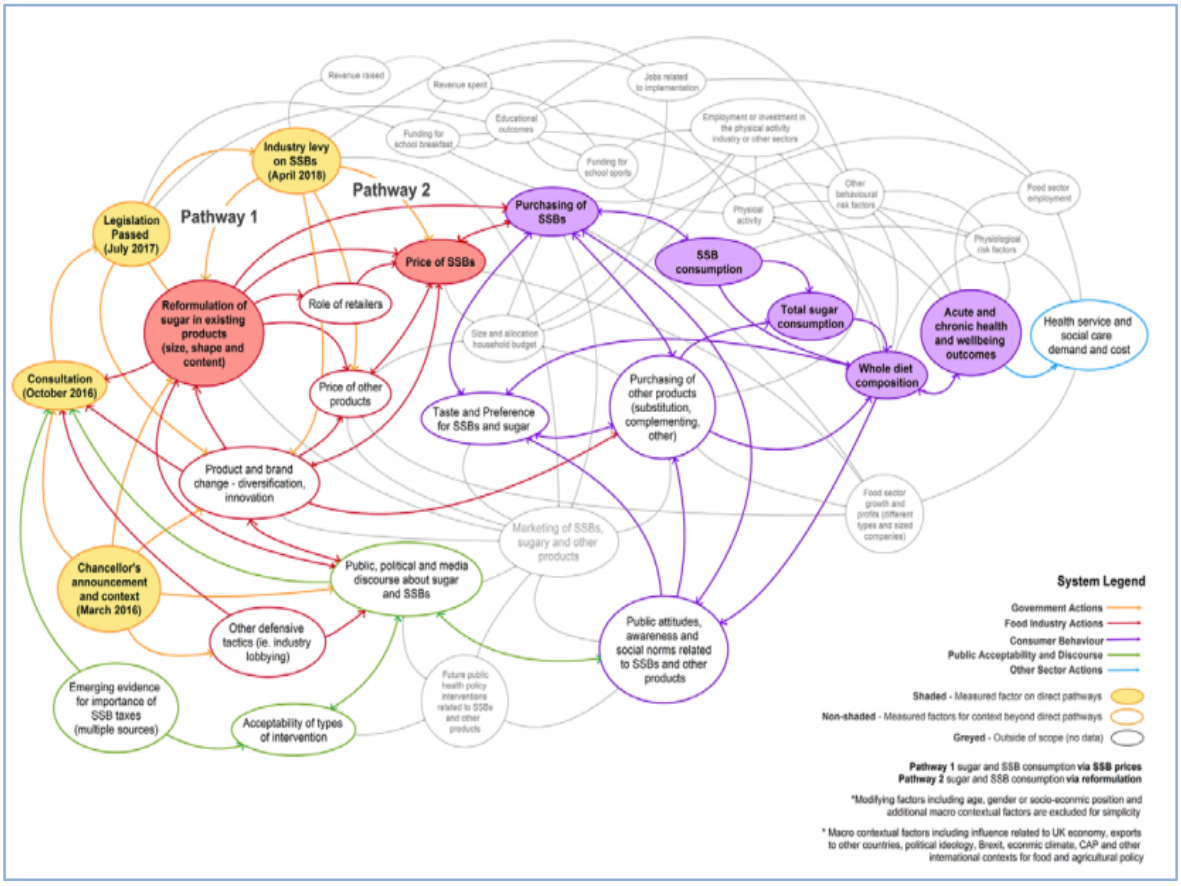


Figure 2.10 *Systems map of the factors that may be impacted by the levy on sweetened beverages*[174]

Many of the factors included in **Figure 2.10** fit into some the groupings devised in the Foresight report.[169] In particular, the categories of *social psychology*, *food production*, *food consumption* and *physiology* are represented and analysis of this system will provide considerable insight into the drivers of unhealthy food consumption in the population. Evaluation of the impact of the sugar tax will elucidate the potential effects of other fiscal interventions, and may help to identify other intervention levers within these categories.

While environmental and interpersonal influences have been considered as parts of complex systems influencing the prevalence of NCDs in the population,[92,174,176,177] at least from a theoretical perspective, more individual factors have not received the same attention. The section of the Foresight map called *individual psychology* includes factors that are specific to an individual, but are not necessarily psychological, such as face-to-face interaction and food literacy. Therefore, factors that act on an individual level, including psychological, emotional and cognitive factors, will be referred to in this thesis as 'individual-level' or 'individual' factors (as opposed to interpersonal or environmental factors). In the COM-B model, these factors would most often fit into the 'Capability' and 'Motivation' categories.[150]

Various individual-level factors have been shown to be associated with diet and physical activity behaviours in observational studies, but their role within a complex system has not been analysed in the same way as environmental factors. This may be the case because population-wide interventions usually target environmental factors, so understanding the role of the environment is a priority. However, pregnancy is a unique period when women have regular contact with healthcare professionals, and may also be more open to changing their health behaviours,[114,178] making individual-level interventions more practical. Therefore, addressing this gap in the literature through detailed exploration of individual-level factors that influence health behaviours in pregnancy, which of these may be modifiable and how they fit in the wider system is warranted.

2.5 Analysis of complex adaptive systems

In order to identify intervention components that are likely to have a meaningful impact on women's heath behaviours in pregnancy, it is necessary to understand how this system may function, and which intervention levers should be pulled to effect the greatest change. There are some common methods for analysing complex systems, including system dynamics, network analysis and agent-based models (ABMs).[148,179] System dynamics models are represented by a diagram comprised of stocks and flows (**Figure 2.11**). Stocks are variables that increase or decrease over time, and the rate of change is represented by flows into or out of the stock.[179] Flows may be influenced by one or many variables, and feedback loops are often part of the models. Systems dynamics models can be very complex, and may include any number of stocks and flows, which are often informed by empirical data. These models are useful for exploring whole system behaviour,[179] but do not allow for the consideration of variation between individuals within the system. As individual factors and behaviours are the focus of this thesis, a system dynamics model is not the correct approach to take here.

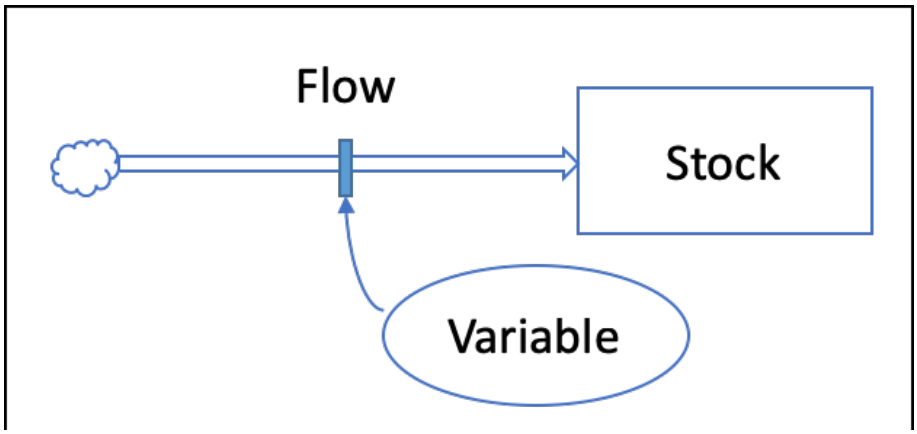


Figure 2.11 *The key elements of system dynamics models are stocks and flows*

Network analysis is particularly useful for analysing social networks, how these networks change over time, and how social influences affect population outcomes.[148,179,180] Rather than analysing individual-level variables, network analysis focuses on the connections between individuals,[181] which may be important in examining disease epidemiology, adoption of new products or behaviours, or the role of social support.[148,179] While social networks will certainly impact on diet and physical activity during pregnancy, this thesis is focused on the individual-level factors that influence these behaviours rather than interpersonal relationships. Therefore, a model that can incorporate individual-level factors would be more appropriate.

2.6 Agent-based modelling

An ABM is appropriate for analysing the CAS model developed in this thesis because a key feature of this type of model is the inclusion of individual behaviour and the variability between individuals. ABMs allow for the emergence of population-level outcomes that may not be seen or predicted on an individual level,[179] thus capturing one of the defining features of a CAS. In an ABM, individual agents are situated within a virtual grid and can interact with their environment and with other agents.[179,182] An agent may be a person, organisation, building, or other entity and agents behave according to a set of rules that are built into the model.[179] Agent parameters are fixed characteristics that can be assigned to agents according to a chosen distribution. If agents represent people, parameters may include gender, income, ethnicity and any other characteristics that are pertinent to the model. Agent variables are also assigned to individuals, and they may change over time according to model rules. Depending on the model, agent variables could include attitudes, choices, behaviours, BMI, and any other factors that are expected to change over time in response to other model elements. This means that, depending on the requirements of the model, individuals may age, change their behaviours based on past experiences or change in other ways as the model runs and these changes will affect the model outcomes.[183] Furthermore, rules and characteristics can be applied in a probabilistic (rather than deterministic) way, allowing for a degree of stochasticity to be included in the model.[179]

The grid within which agents exist is made up of cells and may be simple or detailed. If geography is not important, the grid will likely be a discreet space where agents are randomly distributed and no additional characteristics are assigned to different areas of the grid. On the other hand, some models aim to represent a specific city and use geographic information system (GIS) technology to assign specific characteristics to different areas.[184-187] For example, areas designated as affluent could contain more healthy food outlets and more expensive gyms, and the agents in these areas may have higher incomes and be more educated than in the deprived areas of the grid. The strategy that utilises GIS data is often employed to model public health interventions where environmental factors are key.[187-189]

One of the earliest examples of using an ABM in social research was described by economist Thomas Schelling.[190,191] In the 1970s, Schelling presented a series of experiments to show the way individual preferences can drive population-wide segregation, demonstrating that a preference not to be in a minority amongst neighbours will lead to segregation over time except in cases of total integration. These experiments are often referenced, and are a simple way of demonstrating the key advantages of ABMs, so the simplest of Shelling's experiments has been conducted by hand for demonstration purposes here, and is presented below. In the original publication,[191]

Schelling instructed the reader to draw a grid and randomly distribute two distinct groups of agents within it, leaving 25% of the spaces blank. **Figure 2.12** was produced to meet the initial requirements (50% of dots are green, 50% are blue, and 25% of the cells are empty) and the dots and empty spaces were randomly distributed using a list randomising programme.[192] In this figure, the average proportion of same-colour neighbours each agent has is 49%. A neighbour is defined as an agent occupying one of the eight surrounding cells.

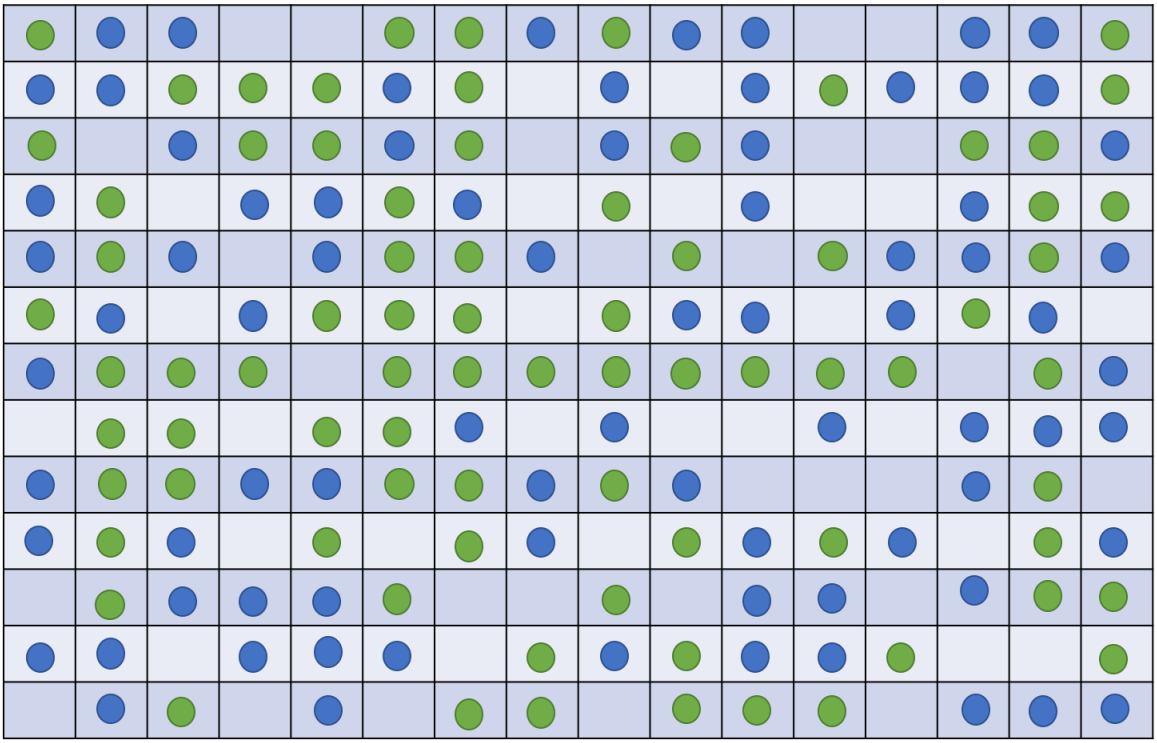


Figure 2.12 *When agents are randomly distributed, the average proportion of same-colour neighbours is approximately 49%. Some individuals are minorities amongst their neighbours, so will need to move to a new position in the grid.*

Next, the reader was to assume that each agent wanted at least half of its neighbours to be the same colour as itself. Each dissatisfied agent (who had fewer than 50% same-coloured neighbours) would move to the nearest empty space that met its requirements. This process continued until every agent on the grid was satisfied and the system was at equilibrium. Agents could be moved according to any systematic pattern, and in the version presented here dots' surroundings were examined starting with the top left cell and ending with the bottom right. If an agent needed to move, it was moved to the nearest cell that met the 50% same-coloured neighbour requirement. The process was repeated, moving from the top left to the bottom right of the grid until all agents were satisfied. The final distribution is shown in **Figure 2.13**.

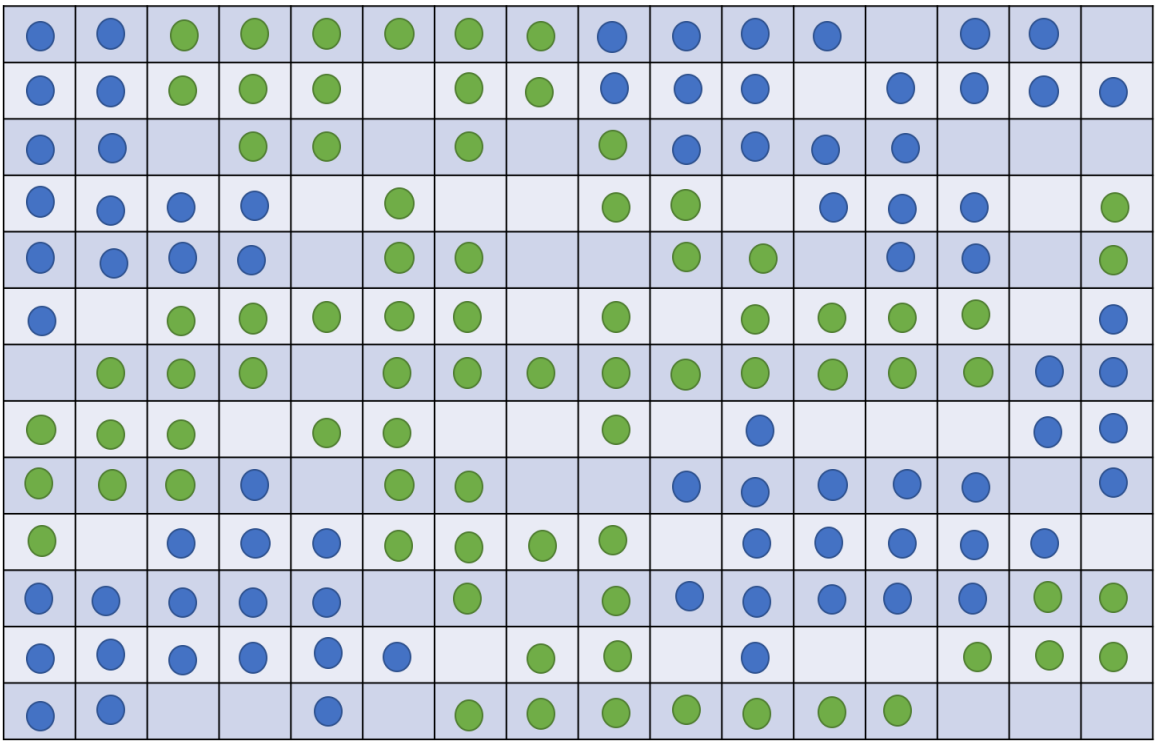


Figure 2.13 *When all dissatisfied agents have moved so that no agent is a minority, there is clear segregation in the grid and the average agent is surrounded by 85% same-coloured neighbours*

Visual inspection shows that an individual requirement not to be part of a minority amongst one's neighbours leads to clear segregation over time. In the original distribution (**Figure 2.12**), the average proportion of same-coloured neighbours each agent had was very close to the required proportion at 49%. After each individual's needs were met (**Figure 2.13**), the average proportion of same-coloured neighbours each agent has is 85%; much higher than the minimum requirement.

Changing various rules in the model would, of course, change the population-wide outcomes in different ways, further demonstrating the potential usefulness of ABM.[190,191] The example presented above demonstrates some of the key characteristics of a CAS; the changes in the system that resulted from individual choices led to an amplified output over time. Indeed, the level of segregation in **Figure 2.13** can be thought of as an emergent property of the system, which could not have been predicted from the knowledge that each agent wanted to live in a neighbourhood where at least 50% of its neighbours were the same colour as itself. Furthermore, the experiments show that an ABM is a good method for exploring these characteristics of a CAS, and of considering the impact of not only individual factors within a system, but also the interaction between them.

2.7 Agent-based modelling in public health

Given its advantages and clear applicability to public health problems, ABMs have been used in a number of public health studies, and these have often examined disease epidemiology. ABMs are ideal for examining disease transmission because interaction between agents is valuable for modelling how contact between individuals can drive the spread of communicable disease.[179] In more recent years, ABMs have been used to model causes of NCDs. The earliest examples focused on the influence of the built environment and its impact on physical activity while more recent models have been more complex and included factors such as social norms and socioeconomic status. Key examples of existing studies that explored influences on diet and/or physical activity are summarised below.

2.7.1 ABMs to model walking behaviour

A number of early examples of using ABMs to predict health behaviours examined the potential influence of the physical environment on walking behaviour in the population. One such study[193] developed a model to analyse how different influences may lead to disparities in walking by SES. Local area factors included safety and proximity. Individual factors were SES, age, work status, place of work, attitude towards walking, dog ownership and social influences. Attitude towards walking changed each day as a function of the day's experience and family/friend behaviour, and this attitude affected the probability of walking along with the individual factors listed above. This model suggested that walking in lower SES neighbourhoods would increase if residents' attitudes towards walking were improved. This could be achieved through both improving neighbourhood safety and increasing the extent to which land use is mixed.[189] That is, by distributing non-residential locations such as workplaces, shops and amenities across a city rather than concentrating them in one area, more people were likely to walk in the model.

In a slightly more complex study,[194] an ABM was used to simulate the effects of two different policies on children's active travel (walking or cycling) to school. They designed different models to represent the effect of distance to school and traffic safety along the route to school. Children's active transport was determined each day by households' perception of the safety of active travel and their attitude towards walking, which in turn was influenced by multiple variables. This study concluded that active travel to school may be increased if schools were evenly distributed in a city and if children were assigned to attend the school nearest to their house. Secondly, they concluded that increasing the road safety more intensively near the school may be more effective in increasing active transport than less intensively increasing the road safety in a larger area.

A third study did not test any interventions, but rather was intended to produce the most useful model for future simulation experiments. Here, three models were compared to represent the 'walkability' of different areas in Buffalo, New York.[195] These models were all compared with survey data and data on the real pedestrian density in different parts of the city. Results showed that an ABM that incorporated built environment, perceptions about areas, and interactions between people was the most realistic and reliable model for representing area walkability.

2.7.2 ABMs to model diet quality

A number of studies have used ABMs to assess the influence of the food environment on diet quality and simulated the potential impact of intervention and policy strategies. In one study, a relatively simple model was used to investigate the factors that influence the difference in diet quality between high-income and low-income households.[196] Households were the agents and each household used a utility function based on store prices, distance to the store, the household's habitual shopping behaviour and household preference for healthy food. Various experiments were run and showed that both increased preference for healthy food and pricing healthy foods to be more affordable were necessary to reduce the unequal distribution of healthy eating between affluent and low-income households.

In another study, an ABM was designed to assess the potential impact of various interventions on the fruit and vegetable consumption of households in 'urban food deserts.'[185] This study used Buffalo, New York as a model population and incorporated real geographic and census data into the model. Through four experimental simulations, the authors found that supporting households to do their food shopping more frequently would increase the number of households stocking fresh produce at any point in time. The models also suggested that making fruit and vegetables more accessible by increasing the number of convenience stores that stock these foods and by implementing mobile farmers' markets would also increase fruit and vegetable consumption.

A relatively comprehensive ABM was developed to test the possible effects on of different types of intervention on diet quality.[186] The US city of Pasadena, California, was used to inform the model and both geographic and survey data were included. A number of factors thought to influence food choice, including attitudes, were used to determine individuals' consumption of fast food and fruit and vegetables. Declining sales induced fast food outlets to switch to selling fruit and vegetables and induced fruit and vegetable outlets to switch to selling fast food, reflecting the interaction between demand for, and availability of, different food types. Food outlets re-assessed their profits quarterly. This study found that promoting norms through advertising was the most effective intervention regardless of other social influences. Fiscal

interventions such as taxation had a moderate impact on diet and regulating the number of fast food outlets in a given area had a minimal impact on diet. This model was then used to assess how a mass media and education campaign could influence social norms and lead to increased consumption of fruit and vegetables in various neighbourhoods in New York City.[188] This simulation assigned a quantitative value to positive social norms and assumed that the campaign would increase the social norm of eating fruit and vegetables by 10% which led to an increase in fruit and vegetable consumption in each neighbourhood of between 2.7% and 13.9%.

Another sophisticated model aimed to identify factors that influenced racial disparities in obesogenic behaviours. This model was designed to represent the whole lifecourse as individuals were born, went to school, worked, had a child, retired and died.[176] There were many factors in the model that were hypothesised to influence health behaviours including neighbourhood income, household income, school attendance, school quality, education level and availability of healthy foods in a given area. Behavioural outcomes of the model were smoking, diet and physical activity. Factors modelled specifically to influence diet, and manipulated in the models, were school quality (represented by student-to-teacher ratios) and social network behaviour where agents changed their perception of a healthy diet to be more similar to their neighbours' perceptions. Through a number of complex experiments, this study found that improving school quality may improve diet quality, and this may also lead to a reduction in the racial disparity in healthy eating. However, none of the simulations resulted in an elimination of racial disparities.

One of the most detailed ABMs for modelling diet quality is called Health Behaviours Simulation (HEBSIM).[187] HEBSIM was designed to model the interaction between households and food outlets using national statistical data and GIS data from a city in the Netherlands. Low-income households preferred unhealthy foods more often than high-income households and food outlets were defined by food quality, price, monthly costs and capital. At each time point, a household's decision about the food outlet from which to purchase food was based on distance from home, price and preference for healthy food. Food outlets would close if their revenue (based on visits) did not exceed monthly costs and new outlets could fill the vacant space. The primary outcome of this simulation model was household visits to a healthy food outlet; a proxy for healthy eating. Once calibrated, the model was used to test the effects on overall healthy food consumption and health inequalities of i) eliminating geographic segregation by SES, such that low-income households and high-income households were not clustered in different areas of the city ii) reducing the price of healthy foods through subsidies and iii) a health education campaign. The experiments found that eliminating segregation led to an increase in healthy food consumption among low-income households, but a decrease among high-income households; thereby reducing inequalities. Reducing the price of healthy foods led to a small increase in healthy food

consumption among low-income households and had a negligible effect on high-income households, which also meant that inequalities were somewhat reduced. The health education campaign led to an increase in healthy food consumption among all households exposed to it, so while overall diet quality improved, there was no reduction in health inequalities between low-income and high-income households.

2.7.3 ABMs to model overweight and obesity

Two ABMs have been designed with changes in BMI as the outcome and both focused on adolescents. One of these models was used to investigate the possible influence of social norms on adolescents' changes in BMI over time.[88] While building in a number of rules to better represent the real world, the model primarily investigated how BMI could change over time if individuals tried to change their BMI to be more similar to their peers. The simulation showed that when the population BMI data were skewed to the right, the average BMI in the population would increase over time.

The other ABM for examining BMI change in adolescents also focused on peer influence and simulated the potential effects of different interventions to address overweight and obesity.[197] The results of this study suggested that in populations with a relatively low prevalence of overweight, stronger peer influence may result in lower BMI across the population. However, stronger peer influence in populations where many individuals were overweight led to an overall increase in BMI. On the other hand, interventions that were targeted at individuals and did not incorporate social influences had little effect on BMI.

2.8 Focus on pregnancy

Given that pregnant women have regular one-to-one contact with healthcare professionals, and that pregnancy often motivates women to change some health behaviours,[85,113] it is worth examining the individual-level factors within a complex system that should be targeted by a behaviour change intervention for pregnant women. Other research groups are beginning to look at public health problems from a CAS perspective, but are focusing on environmental factors and generally targeting the whole population.[174] This project, on the other hand, aims to take advantage of the opportunities presented by pregnancy to intervene at an individual level, so particular attention will be paid to individual-level factors while still taking interpersonal and environmental influences into consideration.

This chapter has shown that conceptualising the factors that influence diet and physical activity in pregnancy as a CAS can have advantages when compared with traditional SCMs and other models

of behaviour, and has demonstrated how CAS models can be examined using ABM. In particular, it is helpful to consider not only the key factors, but also how they may interact over time. Pregnancy may introduce some new factors into this system and some work will be undertaken to identify these. Finally, it is important to consider environmental and contextual factors as these will certainly impact on health behaviours, and they may also interact with the individual-level factors that are the focus of this thesis.

2.9 Conceptual framework

The following conceptual model has been developed as a visual representation of the factors that interact during pregnancy to influence diet and physical activity (**Figure 2.14**) and this model can apply to individuals or to a population of pregnant women. While some existing diagrams of complex systems were consulted, this framework is not an adaptation of any one in particular. Key factors that influence diet and physical activity in pregnancy will be identified within this thesis and the figure will be revisited and updated in subsequent chapters. As no factors were selected *a priori*, the model is now populated with coloured dots, which will be replaced as the figure is updated. Diet quality and physical activity are shown as individual factors within the system and nutritional status and body composition are properties that emerge from the system as neither nutritional status nor body composition can be predicted by any one behaviour or individual factor. The environmental factors that are known to influence health behaviours, which are outlined in **Section 1.5**, are also included in the model and are assumed to interact with the whole system. These are accessibility, [75,76] affordability,[74] promotion [77] and social norms. [79-81]

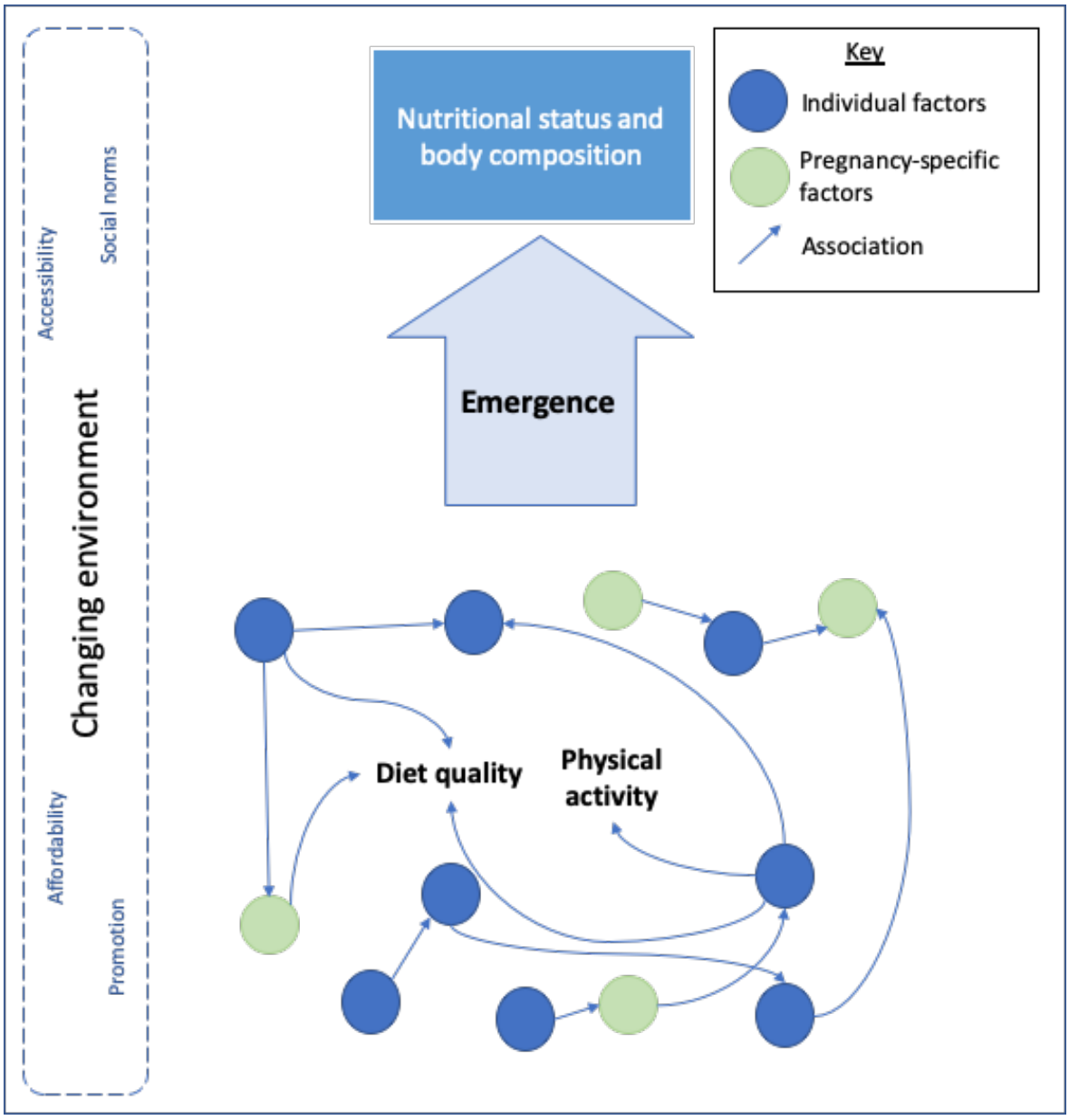


Figure 2.14 *Preliminary conceptual framework representing the CAS of factors that influence diet and physical activity in pregnancy*

Chapter 3 Which individual-level factors are associated with diet and physical activity behaviours in women of childbearing age?

3.1 Introduction

There are many environmental, interpersonal and individual factors that interact to influence diet and physical activity. Individual-level factors include psychological, cognitive and demographic characteristics, and are often significant predictors of health behaviours such as diet and physical activity. Indeed, many studies have concluded that public health interventions to improve these behaviours should take individual differences into account and aim to change key factors such as those described in **Section 0**.[76,110] Data for this study were collected as part of the Southampton Initiative for Health (SIH), and findings of this analysis will help to identify individual-level factors that are associated with diet and physical activity in women of childbearing age, informing the development of the CAS model described in Chapter two.

3.1.1 Southampton Initiative for Health

This chapter comprises a secondary analysis of survey data from women attending Sure Start Children's Centres (SSCCs) in Southampton, Gosport and Havant as part of the SIH. The SIH was a non-randomised controlled evaluation of a complex intervention whereby SSCC staff were trained in Healthy Conversation Skills (HCS); a programme of skills to support behaviour change.[110] HCS will be described in more detail in **Section 5.1.1**. The aim of the SIH intervention was to support women attending SSCCs and empower them to improve their diet quality and increase their levels of physical activity through contact with HCS-trained staff in Southampton. Centres in Gosport and Havant, where staff were not trained in HCS, served as controls.[110] This study showed that HCS-trained staff used the HCS skills significantly more often than staff in the control centres, but this did not translate to a significant improvement in diet or increase in physical activity in women attending the centres.[198] However, women attending the intervention centres did show a significantly smaller decline in self-efficacy and perceived control than did women in the control centres, suggesting a protective effect of the intervention on these factors.[198]

3.1.2 Individual-level factors assessed

The factors that were considered possible predictors of diet quality and physical activity levels in the SIH study were identified from existing literature on behaviour change and on previous work with women in the Southampton area, including focus groups and an earlier study conducted within SSCCs.[100] Self-efficacy and perceived control were the key factors thought to be potential mediators of the effect of the intervention on changes in diet or physical activity in the SIH.[110] This is because studies of low-income or less educated women have shown that health behaviours such as diet and physical activity were associated with the extent to which women felt in control of their lives and able to eat well or exercise.[110,198,199] Furthermore, increasing self-efficacy has been shown in some trials to lead to an increase in fruit and vegetable consumption.[95] Self-efficacy was thought to be a prerequisite for perceived control; a woman's belief that she had control over her life.[107,108,110] The principle that self-efficacy and perceived control are associated with health behaviours such as diet and physical activity, and the hypothesis that increasing these would lead to improvements in such behaviours, underpinned the SIH intervention.[110]

Other factors that were measured in the SIH study included social support for purchasing fruit and vegetables, outcome expectancies and food involvement. For a detailed description of how each of these constructs was measured, see **Appendix A**. Social support for purchasing fruits and vegetables referred to how often family members asked or reminded women to purchase fruit and vegetables, or approved when they purchased these foods.[99,111] Outcome expectancies assessed whether women believed there would be positive consequences of eating healthy foods. These included whether women thought that a healthy diet would benefit their health, their appearance and their happiness.[112] Food involvement measured the priority that women gave to food in their lives and included two subscales: 'cooking and eating' and 'setting and disposal.'[101,102]

While self-efficacy and perceived control in the SIH study were analysed and findings published,[198] much of the remaining survey data has not yet been analysed. However, similar survey data were collected from women attending SSCCs in Southampton in an earlier study in 2007,[100] and a path analysis was conducted. Here, a model that explained 21% of the variance in diet quality suggested that self-efficacy, perceived control and outcome expectancies were associated with diet quality in women educated to GCSE level and below, but these associations were not significant in those of higher educational attainment. Social support for healthy eating and food insecurity were also shown to be independently associated with diet quality in that earlier study.[100]

3.1.3 Rationale for conducting this analysis

While the questionnaire data presented in this chapter were not collected from pregnant women, the data nonetheless have the potential to contribute to the complex systems model of factors that influence health behaviours. The survey data collected through the SIH study include information about women who are mothers of young children, and are of childbearing age. Data include diet quality, physical activity levels, and individual-level factors including socioeconomic and psychological factors. Furthermore, Sure Start aims to provide services to more deprived families,[200] so the data analysed here should represent the less advantaged families in Hampshire, which is potentially useful for the development of public health interventions that do not contribute to inequalities in health. This quantitative analysis of survey data from women in Southampton and the surrounding area will complement the analysis in Chapter five, which comprises a qualitative study of pregnant women in Southampton. Combined, these two chapters will contribute to a more complete picture of the factors that affect women's health behaviours.

Traditional statistical methods such as linear regression analyses are typically used to identify individual driving forces and linear relationships, as is being done in this chapter, and do not aim to define complex relationships and interactions within a system.[201] However, it is necessary first to understand which modifiable factors are associated with the behaviours of interest and explore how they are related to begin to develop an evidence-based model. Therefore, this chapter aims to identify some of the factors that are associated with diet quality and levels of physical activity in women with young children, and the analysis will be a first step in informing the CAS framework that is being developed in this thesis.

3.1.4 Research question

This chapter aims to partially address research question two: *What modifiable factors are associated with diet and physical activity behaviours, and changes to these behaviours in pregnancy?*

3.2 Methods

3.2.1 The SIH follow-up survey

Survey data were collected as part of the SIH complex intervention study, which was run across 14 SSCCs in Southampton (intervention) and 14 SSCCs in Gosport and Havant (control). Outcomes were evaluated using a cross-sectional survey at two time points. The first set of questionnaires was completed before staff were trained in HCS (January-July 2009) and the second set of questionnaires was completed 1 year post-training (April-October 2011). The questionnaires were completed opportunistically within SSCCs by women who were attending; while there were some participants who completed both the first and second wave of questionnaires, the cohorts did not necessarily consist of the same women. Therefore, the data are not conducive to individual-level analysis of change over time, but the set of questionnaires collected at one time point provide cross-sectional data appropriate for an observational study.

This study is a secondary data analysis of questionnaires that were completed at the second time point as the data are more recent and include more participants than the baseline set. To complete the questionnaires, women attending SSCCs were interviewed by researchers who were not involved in delivering the intervention and were not otherwise involved with any aspects of running the SSCCs.[198] Follow-up questionnaires were completed by 921 women across all 28 centres. While the allocation to intervention versus control was not expected to influence the findings of this cross-sectional analysis, differences between groups were analysed using two sample t-tests (continuous variables), chi^2 (binary variables) or Kruskal-Wallis tests (ordinal variables). The purpose of making these comparisons was to determine whether there were any systematic differences between women in Southampton and those in Gosport and Havant that may influence the findings of the analysis because previous similar studies have focused exclusively on women in Southampton.[69,100]

3.2.2 Outcome variables

Diet quality was assessed using a 'prudent diet' z-score, as developed by Crozier *et al* from Southampton Women's Survey (SWS) data.[202] Here, a sample of 6,125 SWS participants completed a 100-item FFQ and principal components analysis (PCA) was used to identify distinct dietary patterns. The first principal component was characterised by high intakes of vegetables, whole grains, vegetarian foods and pasta and low intakes of full-fat milk, red meat, savoury snacks, white bread, sugar and processed foods (**Table 3.1**).[202] The twenty most influential items; those with the greatest absolute value PCA coefficients, were used to produce a 20-item FFQ that

would be more pragmatic than the long form FFQ while still representing overall diet quality. The 20-item FFQ was shown to be highly correlated with the 100-item form (Pearson's Correlation Coefficient = 0.94).[202] Individuals' diet quality scores are calculated by multiplying each item's PCA coefficient by the standardised weekly consumption of that item and then summing the products, and this results in a diet quality z-score (with a mean of 0 and standard deviation of 1) for each participant.[110,198]

Table 3.1 *Items included in the 20-item FFQ and their PCA coefficients*[202]

Food or food group	PCA coefficient
Peppers	0.20
Tomatoes	0.19
Vegetable dishes	0.19
Courgettes, marrows and leeks	0.19
Green salad	0.17
Wholemeal bread	0.16
Onions	0.16
Vegetarian foods	0.15
Pasta	0.15
Spinach	0.14
Full-fat milk	-0.14
Beef	-0.14
Crisps and savoury snacks	-0.15
Yorkshire puddings/ savoury pancakes	-0.15
White bread	-0.16
Sugar	-0.17
Gravy	-0.18
Sausages	-0.19
Meat pies	-0.19
Chips and roast potatoes	-0.21

Physical activity levels were measured using the General Practice Physical activity Questionnaire (GPPAQ).[203] While the GPPAQ includes questions about walking, housework and gardening, best practice guidance states that these are included to allow participants to record such activities, but the resulting data do not contribute to an understanding of overall physical activity and inclusion of walking requires further detailed discussion with the practitioner.[203] Therefore, physical activity scores not including walking were used in these analyses. GPPAQ scoring grouped participants into four categories of physical activity: inactive; moderately inactive; moderately active and active. These were defined by how sedentary or active women's jobs were and how much time they spent cycling or doing exercise such as swimming, jogging or aerobics, as shown in **Table 3.2**.[203] Only those who fell into the 'active' category were considered to be meeting current physical activity guidelines of 30 minutes of moderate activity five times per week[204] and GPPAQ guidance recommends that all patients who do not fall into the 'active' category should be

offered a brief intervention to increase physical activity.[203] For these reasons, participants were divided into two groups for the analyses presented here; insufficiently active (GPPAQ categories inactive, moderately inactive, and moderately active) and sufficiently active (GPPAQ category active only).

Table 3.2 *Categories of physical activity as assessed by the GPPAQ[203] and corresponding binary categories used here*

Physical exercise and/or cycling (hr/week)	Sedentary occupation	Standing occupation	Physical occupation	Heavy manual occupation
0	Inactive	Moderately inactive	Moderately active	Active
Some but <1	Moderately inactive	Moderately active	Active	Active
1-2.9	Moderately active	Active	Active	Active
≥3	Active	Active	Active	Active

Green	=Sufficiently active
Yellow	=Insufficiently active

3.2.3 Confounding variables

Demographic characteristics including age, number of children, home index of multiple deprivation (IMD) and food security were considered to be potential confounders and such characteristics are usually adjusted for in similar studies.[100,198] Educational attainment has often been shown to predict women's quality of diet,[69,100,101,103] and here this was categorised into six groups where the lowest was no qualifications and the highest was degree level and above. Given that a number of studies have found educational attainment to be a key predictor of health behaviours, as well as affecting the strength of association between diet quality and other factors,[69,100,101,103] educational attainment was given particular attention here. Where appropriate, data were divided by women's educational attainment into two groups; lower educational attainment (up to GCSE inclusive) and higher educational attainment (beyond GCSE). The factors described in **Section 0** were assessed as outlined below, and all questionnaire items can be found in **Appendix A**.

3.2.4 Individual-level factors that may influence diet and physical activity

Self-efficacy is often associated with diet quality[95,96,205,206] and level of physical activity[93,94] and in the SIH study, both general and behaviour-specific self-efficacy were measured using validated tools.[110] Firstly, general self-efficacy was assessed using five items from the General Self-Efficacy Scale.[207] Women were asked how much they agreed with statements about their ability to solve problems and reach goals, and responses were given in four options from 'strongly disagree' to 'strongly agree.' The self-efficacy for healthy eating and for physical activity scales were taken from Renner (2003)[112] and included five items each. The healthy eating section began with the heading 'I could stick to eating healthy foods even if…' and items included potential barriers to maintaining a healthy diet. The physical activity section began with the heading, 'I could stick to an exercise routine even…' In both of these scales, responses were given in four options as with general self-efficacy.

Perceived control is closely related to self-efficacy and also associated with diet quality and physical activity in women.[76,103] In the SIH study, perceived sense of control was measured using a scale from Marmot (1991),[208] which has been used in other studies.[209] This scale consisted of nine items about women's perceived control over their lives and their ability to influence their future. Responses were given in four options from 'strongly disagree' to 'strongly agree.'

Social support for healthy eating scale referred to how often women's families supported them to purchase healthy foods. In the SIH questionnaire, this was assessed using a validated five-item scale with five possible responses ranging from 'never' to 'very often.'[111] Questions asked how often family members approved when they purchased fruit and vegetables, asked them to buy fruit and vegetables, reminded them to buy fruit and vegetables, bought fruit and vegetables themselves and talked to the women about buying fruit and vegetables.

Positive outcome expectancies for healthy eating assessed whether women thought there would be desirable consequences of healthy eating. This has been shown previously to affect diet score in women of low educational attainment, but not in those educated beyond GCSE.[100] For this study, outcome expectancies were measured using a validated six-item scale, which asked women how much they agreed with statements about the outcomes of eating healthy foods such as "I'll feel physically more attractive" and "It will be good for my blood pressure."[112,210] Responses were given on a four-point scale from 'strongly disagree' to 'strongly agree.'

Finally, food involvement, which is a measure of the priority women give to food in their lives, has been shown to predict diet quality, and also to be associated with educational attainment.[101] Here, the food involvement scale validated by Bell and Marshall (2003) was used.[102] This

comprised 12 items about women's attitudes towards food. The items on the food involvement scale can be divided into two sub-scales; one is related to setting and disposal while the other is related to cooking and eating. Both subscales are also considered here.

3.2.5 Spearman correlation matrix

Correlations between all variables were first explored by producing a correlation matrix using Stata SE version 14. Spearman's correlations were more appropriate than Pearson's correlations because of the nature of the data. Pearson's correlations require variables to be normally distributed and measured on interval scales while Spearman's correlations are nonparametric and can be used for ordinal data.[211]

3.2.6 Directed acyclic graphs

In order to develop individual regression models, a directed acyclic graph (DAG) was produced for each potential determinate of diet quality and of physical activity. DAGs are increasingly used to inform the development of regression models to make underlying assumptions explicit and to prevent over-adjustment.[212,213]

In order to produce a DAG, one exposure variable and one outcome variable are selected. Potential confounders are also put into the diagram with arrows between factors to indicate hypothesised causation.[213] This diagram can then be used to visualise which factors may be defined as confounding factors (factors that influence both the exposure variable and the outcome, but do not lie on the causal pathway between the exposure and the outcome). For this study, the DAGs were produced using the website dagitty.net,[214] which allows the user to produce a DAG and identifies which variables can be defined as confounders, and should be included in a regression model. All of the DAGs produced for this study are shown in **Appendix B**. The factors selected for each DAG are described in the Results in **Section 3.3.3**.

Determinants being tested were based on the results of the Spearman correlation matrix and on evidence from previous research. These included general self-efficacy, self-efficacy for healthy eating, self-efficacy for physical activity, social support for purchasing fruit and vegetables, perceived control, positive outcome expectancies, food involvement, and the cooking and eating sub-scale of food involvement. Potential confounders included in the models for diet were age at interview, educational attainment, number of children, food security and home IMD. Potential confounders in the models for predictors of physical activity levels were age, educational attainment, number of children and home IMD.

3.2.7 Multiple linear regression analyses to test for associations between individual factors and diet quality

Because the outcome variable (prudent diet z-score) was a continuous variable, multiple linear regression analyses were performed to assess the relationships between independent variables and this outcome.[215] Variables included in the analyses were determined by the DAGs produced as discussed above. These regression analyses were run in Stata SE version 14. First, individual multiple linear regression analyses were run to determine whether there was a significant association between the input variable and quality of diet, controlling for identified confounders. Both unadjusted and adjusted models were run for each input variable.

Next, an interaction term was used to test whether the association between diet and the input variable differed between women of lower and higher educational attainment. As mentioned above, the effects of educational attainment were closely examined because previous studies have found that education does interact with other factors in their association with diet quality.[96,101,103]

Finally, a combined model, which included all input variables and potential confounders was produced. However, as food involvement and the cooking and eating sub-scale of food involvement were highly correlated, only the total food involvement score was included to avoid multicollinearity in the model.[216]

3.2.8 Binary logistic regression analyses to test for associations with levels of physical activity

As described in **Section 3.2.2**, participants completed the GPPAQ, which categorised them as inactive, moderately inactive, moderately active or active. These scores were dichotomised so that all participants not falling into the active category were considered to be insufficiently active. This binary outcome was then entered into binary logistic regression analyses based on the DAGs to identify factors that were significantly associated with odds of being sufficiently active. Potential predictors of physical activity were general self-efficacy, self-efficacy for physical activity and perceived control. Both unadjusted and adjusted models were produced. As with diet quality, an interaction term was used with each of the input variables to test for an interaction with educational attainment. A combined model was also produced.

3.3 Results

3.3.1 Participants

Six study participants did not have any children, and as this study is focused on mothers, these six participants were excluded from the analyses. In addition, six women were aged over 45 years at interview, and these were also removed as they were assumed to be attending as grandmothers, and were not of childbearing age. Therefore, a total of 909 women were included in all subsequent analyses. The average age of participants was 32.3 years and age ranged from 17 to 45 years. Most women had one or two children, and the maximum number of children was seven. The average age of the youngest child was 1.7 years and almost all (90%) had a child aged 3 years or younger. Most women were educated to A-level or above and most women were White. While the women in Gosport and Havant were largely similar to women in Southampton, there were significant differences in the ethnic distribution where a greater proportion of participants in Gosport/Havant were White. There was also a significant difference in the level of deprivation as Southampton had a greater proportion of women living in areas with an IMD in the most and second most deprived quintiles. Despite these demographic differences, diet quality and level of physical activity was not significantly different between these groups. Participants' characteristics are shown in **Table 3.3**.

Table 3.3 *Demographic characteristics of SIH follow-up survey participants*

Descriptor	All participants N=909	Intervention (Southampton) N=465	Control (Gosport and Havant) N= 444	Difference between groups p-value
Age at interview (y), $\bar{x}$ (SD)	32.3 (5.49)	32.1 (5.66)	32.4 (5.31)	0.391
Number of children, N (%)				0.848
1	367 (40.4)	184 (39.6)	183 (41.2)	
2	371 (40.8)	196 (42.2)	175 (39.4)	
3	123 (13.6)	61 (13.1)	62 (14.0)	
4	32 (3.5)	17 (3.7)	15 (3.4)	
5	10 (1.1)	4 (0.9)	6 (1.4)	
6	4 (0.4)	1 (0.2)	3 (0.6)	
7	2 (0.2)	2 (0.4)	0	
Age of youngest child (y), N (%)				0.908
0	256 (28.2)	130 (28.0)	126 (28.4)	
1	169 (18.6)	81 (17.4)	88 (19.8)	
2	249 (27.4)	141 (30.3)	108 (24.3)	
3	140 (15.4)	62 (13.3)	78 (17.7)	
4	53 (5.8)	27 (5.8)	26 (5.8)	
5+	42 (4.6)	24 (5.2)	18 (4.0)	
Educational attainment, N (%)				0.393
None	19 (2.1)	12 (2.6)	7 (1.6)	
GCSE (grade D or lower)	82 (9.0)	37 (8.0)	45 (10.1)	
O level or GCSE (grade A,B,C)	222 (24.4)	123 (26.5)	99 (22.3)	
A level	270 (29.7)	122 (26.3)	148 (33.3)	
HND/Teaching Certificate or NVQ4	45 (5.0)	17 (3.7)	28 (6.3)	
Degree or NVQ5	258 (28.4)	143 (30.8)	115 (25.9)	
Other	10 (1.1)	10 (0.2)	0	
Ethnicity, N (%)				
White	857 (94.3)	425 (91.4)	432 (97.3)	<0.001
Black (African, Caribbean, other)	11 (1.2)	8 (1.7)	3 (0.7)	0.150
Asian (Indian, Chinese, other)	28 (3.1)	22 (4.7)	6 (1.4)	0.003
Other	13 (1.4)	10 (2.2)	3 (0.7)	0.061
Home index of deprivation,* N (%)				<0.001
1	177 (19.5)	112 (24.1)	65 (14.6)	
2	178 (19.6)	103 (22.2)	75 (16.9)	
3	244 (26.4)	119 (25.6)	125 (28.2)	
4	114 (12.5)	47 (10.1)	67 (15.1)	
5	125 (13.8)	44 (9.5)	81 (18.2)	
In receipt of benefits, N (%)	372 (40.9)	197 (42.4)	175 (39.4)	0.37
Prudent diet score, $\bar{x}$ (SD)	-0.004 (1.00)	0.030 (1.05)	-0.041 (0.95)	0.29
Physical activity category N (%)				0.680
Inactive	399 (43.9)	206 (44.3)	193 (43.5)	
Moderately inactive	149 (16.4)	83 (17.8)	66 (14.9)	
Moderately active	196 (21.6)	89 (19.1)	107 (24.1)	
Active	165 (18.2)	87 (18.7)	78 (17.6)	

*Home address IMD quintile where 1=most deprived

3.3.2 Spearman correlation matrix

The Spearman correlation matrix is presented in **Table 3.4.** This table shows that all variables except the 'setting and disposal' sub-scale of food involvement were significantly associated with prudent diet z-score. For this reason, all variables except food involvement (setting and disposal) were included in further diet analyses. Few of the factors assessed were relevant to physical activity level, and the correlation matrix shows that level of physical activity was only significantly associated with three psychological factors; general self-efficacy, self-efficacy for physical activity and food involvement (cooking and eating). However, food involvement is not obviously relevant to physical activity, so this association was not investigated in further analyses. Many of the variables analysed were significantly correlated with one-another.

Table 3.4 *Spearman correlation matrix showing correlation coefficients between all variables*

	Diet score	Education	Age	Number of children	Home IMD	Food security	General self-efficacy	Self-efficacy eating	Self-efficacy physical activity	Social support	Perceived control	Outcome expectancies	Food involvement (FI)	FI (cooking)	FI (setting)
Diet score	1														
Education	**0.412****	1													
Age	**0.244****	**0.243****	1												
Number of children	**-0.121***	**-0.177****	**0.182****	1											
Home IMD	**0.248****	**0.302****	**0.256****	**-0.100***	1										
Food security	**-0.187****	**-0.190****	**-0.213****	**0.088***	**-0.163****	1									
General self-efficacy	**0.088***	**0.104***	-0.006	-0.043	0.065	**-0.144****	1								
Self-efficacy eating	**0.186****	0.060	-0.004	-0.025	**-0.069***	-0.025	**0.073***	1							
Self-efficacy physical activity	**0.108***	0.053	-0.005	0.001	**0.107***	**-0.111***	**0.278****	**0.210****	1						
Social support	**0.105***	**0.091***	0.028	**0.118***	0.064	-0.047	0.037	**0.074***	**0.148****	1					
Perceived control	**0.282****	**0.352****	**0.101***	**-0.152****	**0.194****	**-0.199****	**0.371****	**0.163****	**0.207****	0.063	1				
Outcome expectancies	**0.228****	**0.144****	0.073	-0.062	**0.126***	**-0.068***	**0.124***	**0.327****	**0.131****	**0.125***	**0.266****	1			
Food involvement (FI)	**0.198****	**0.170****	0.062	-0.016	**0.138****	-0.042	**0.176****	**0.184****	**0.116***	**0.095***	**0.304****	**0.252****	1		
FI (cooking)	**0.212****	**0.213****	**0.097***	-0.012	**0.151****	-0.065	**0.143****	**0.164****	**0.093***	**0.102***	**0.298****	**0.244****	**0.941****	1	
FI (setting)	0.032	-0.054	**-0.070***	-0.014	0.010	0.046	**0.143****	**0.113***	**0.093***	0.014	**0.118***	**0.104***	**0.482****	**0.156****	1
Physical activity	**0.119***	0.048	0.054	-0.025	**0.082***	-0.027	**0.065***	0.050	**0.297****	0.027	0.047	0.029	0.063	**0.074***	-0.008

*p≤0.05
**p≤0.001

3.3.3 Directed acyclic graphs

In all DAGs, the relationships between the potential demographic confounders were assumed to be the same, and all potential confounders were considered to influence participants' diet quality or level of physical activity. **Figure 3.1** shows the assumptions that are common to all DAGs for diet quality and **Figure 3.2** shows the assumptions that were common to the DAGs for physical activity. These figures were used as templates for all of the DAGs that were produced. Firstly, participant age was assumed to influence number of children. Age was also assumed to influence education as all women completing the survey were mothers, and women who have children at a younger age are less likely to complete a high level of education.[217] Similarly, age was assumed to influence food security and deprivation as age at first birth has been linked to measures of poverty.[218] The correlation matrix also shows that many of these characteristics were significantly associated with participant age.

Number of children was assumed to influence food security, at least among the more deprived, as parenthood has been shown to mediate the relationship between lower educational attainment and poverty in some women,[218] suggesting that women with more children may be under more pressure to purchase enough food for their families.

Education was assumed to influence number of children in these models as there is a negative association between education and parity.[217] Educational attainment was also assumed to affect level of deprivation as those who are more educated generally have greater earning potential. While it could be argued that the causation is bi-directional in both of these cases, a DAG only allows for unidirectional relationships so education is modelled here as affecting both parity and deprivation. Education was not assumed to influence food security directly. Food security was assumed to affect diet quality only and index of deprivation was assumed to influence food security as those who are more deprived may struggle more to pay for food.

Food security was not considered to be a factor that influenced physical activity, so was not included in any DAGs for analysing levels of physical activity. There was no association between number of children and physical activity in the Spearman correlation matrix, so number of children was also excluded from the physical activity DAGs.

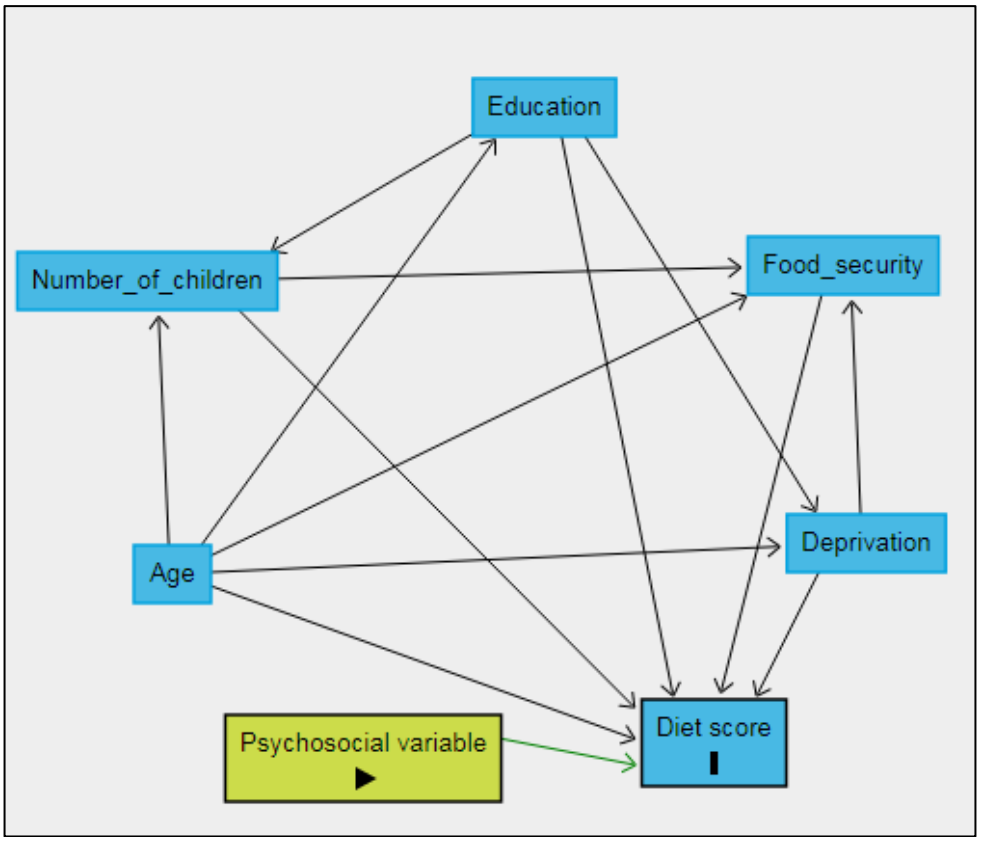


Figure 3.1 *DAG template for diet quality*

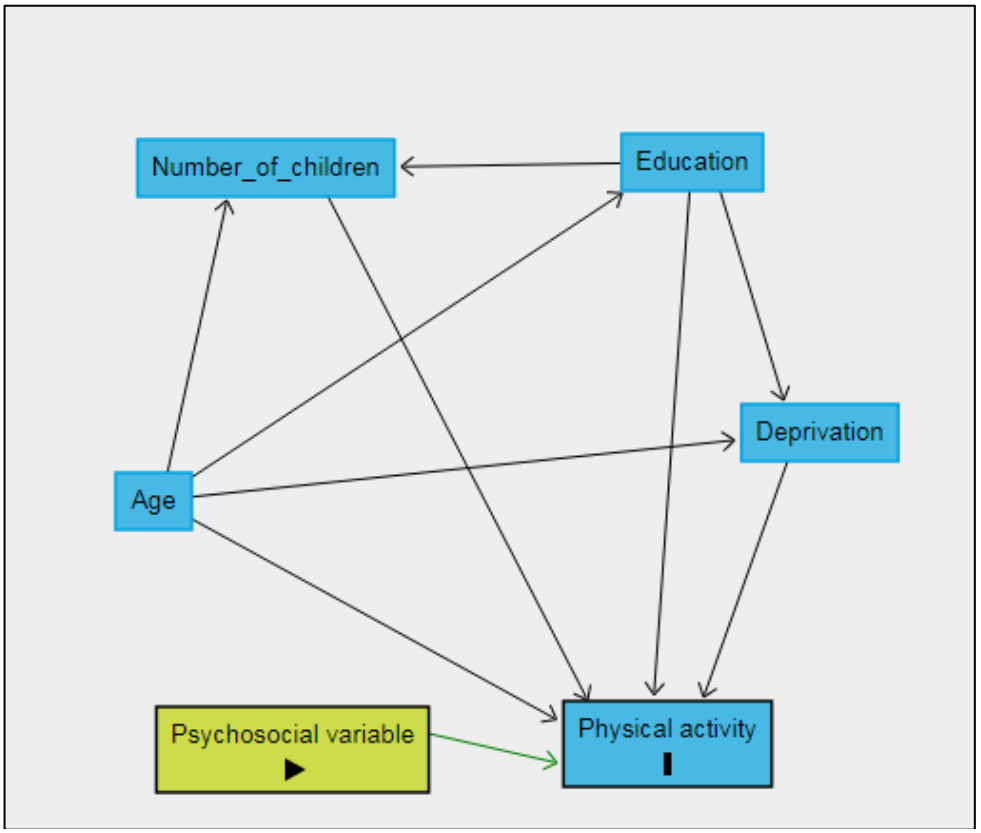


Figure 3.2 *DAG template for physical activity*

Individual variables were entered in dagitty.net[214] to produce DAGs that would inform the models. In the diet quality analyses, self-efficacy and self-efficacy for healthy eating were assumed to have the same relationships with potential confounders. Similarly, self-efficacy and self-efficacy for physical activity were treated the same way in the physical activity analyses. All of the final DAGs are shown in **Appendix B** and confounders included in each model are shown in **Table 3.5**.

Table 3.5 *Confounders included in each regression model, as identified by DAGs*

Outcome variable	Individual factor	Confounders identified by DAG
Prudent diet z-score	Self-efficacy	Educational attainment, food security, perceived control, social support
	Perceived control	Home IMD, educational attainment, food security, number of children, self-efficacy
	Social support	Educational attainment, number of children
	Outcome expectancies	Educational attainment, social support
	Food involvement	Home IMD, educational attainment, food security, number of children, outcome expectancies, self-efficacy
Physical activity category (insufficient vs sufficient)	Self-efficacy	Educational attainment, perceived control
	Perceived control	Educational attainment, self-efficacy

3.3.4 Predictors of diet quality

To identify factors associated with diet quality, individual multiple linear regression models were run based on the DAGs in **Appendix B.** These associations were then explored further by producing a combined linear regression model, which included all significant input variables and was adjusted for all of the confounding variables identified in the individual DAGs. Results of unadjusted and adjusted models are shown in **Table 3.6** and results from the combined model are shown in **Table 3.7**.

Table 3.6 *Associations between prudent diet score and psychosocial variables from unadjusted and adjusted linear regression models*

Psychological variable	Unadjusted model		Adjusted model	
	β coefficient (95% CI)	P-value	β coefficient (95% CI)	P-value
General self-efficacy	**0.088 (0.014, 0.095)**	**0.008**	-0.012 (-0.052, 0.027)	0.539
Self-efficacy for healthy eating	**0.186 (0.058, 0.118)**	**<0.001**	**0.067 (0.039, 0.094)**	**<0.001**
Social support for fruit and vegetables	**0.105 (0.008, 0.032)**	**0.002**	**0.015 (0.003, 0.026)**	**0.013**
Perceived control	**0.014 (0.097, 0.153)**	**<0.001**	**0.064 (0.033, 0.095)**	**<0.001**
Outcome expectancies	**0.228 (0.069, 0.123)**	**<0.001**	**0.069 (0.045, 0.094)**	**<0.001**
Food involvement (total)	**0.198 (0.027, 0.053)**	**<0.001**	**0.017 (0.004, 0.030)**	**0.009**
Food involvement (cooking and eating)	**0.212 (0.033, 0.062)**	**<0.001**	**0.019 (0.005, 0.033)**	**0.009**

Table 3.7 *Results from the combined linear regression model, including all input variables and confounding factors**

Variable	β coefficient (95% CI)	P-value
Self-efficacy	-0.014 (-0.054, 0.025)	0.474
Self-efficacy for healthy eating	**0.045 (0.015, 0.075)**	**0.003**
Social support	0.009 (-0.003, 0.020)	0.137
Perceived control	**0.039 (0.007, 0.071)**	**0.018**
Outcome expectancies	**0.043 (0.016, 0071)**	**0.002**
Food involvement (total)	0.011 (-0.002, 0.024)	0.104

*Model adjusted for educational attainment, food security, home IMD and number of children

Self-efficacy

While self-efficacy was significantly positively associated with diet quality in the unadjusted linear regression analysis, this was no longer the case when adjusting for confounding. Indeed, in both the adjusted model (**Table 3.6**) and the combined model (**Table 3.7**), this association had the highest p-value.

However, self-efficacy for healthy eating was significantly positively associated with diet quality in the unadjusted model, and this association remained highly significant when controlling for educational attainment, food security, perceived control and social support for purchasing fruit and vegetables. It was also highly significantly associated with diet quality in the combined model, which included all input variables. There was no significant interaction with educational attainment (p=0.164).

Social support for purchasing fruit and vegetables

Social support for purchasing fruit and vegetables was significantly positively associated with diet quality, controlling for educational attainment and number of children. However, this association was not significant in the combined regression model.

Perceived control

Perceived control was significantly associated with diet quality in all models: the unadjusted model; the adjusted model controlling for home index of deprivation, educational attainment, food security, number of children and general self-efficacy; and the combined model. There was no significant interaction with educational attainment (p=0.362).

Outcome expectancies

Outcome expectancies were significantly positively associated with diet quality in all models. There was no significant interaction between outcome expectancies and educational attainment (p=0.222).

Food involvement

In the individual regression models, food involvement was significantly positively associated with diet quality and the cooking and eating sub-scale of food involvement was also significantly associated with diet quality. Neither total food involvement (p=0.607) nor the cooking and eating sub-scale of food involvement (p=0.744) significantly interacted with educational attainment.

As stated in the Methods, the cooking and eating sub-scale of food involvement was excluded from the combined model in order to avoid collinearity with the total food involvement variable.[216] In the combined model, food involvement was not significantly associated with diet quality.

3.3.5 Predictors of physical activity

Self-efficacy and perceived control were included in binary logistic regression models to assess their association with physical activity. Physical activity was dichotomised into 'insufficiently active' and 'sufficiently active' so the analyses assessed whether general self-efficacy, self-efficacy for physical activity or perceived control predicted significantly increased odds of a sufficient level of physical activity. As with diet quality, interaction with educational attainment was assessed. The results of the individual models are shown in **Table 3.8** and the results from the combined model are shown in **Table 3.9**.

Table 3.8 *Associations between psychological factors and level of physical activity from unadjusted binary logistic regression analyses*

Psychosocial variable	Unadjusted model		Adjusted model	
	Odds ratio (95% CI)	p-value	Odds ratio (95% CI)	p-value
General self-efficacy	1.072 (0.966, 1.190)	0.191	1.039 (0.928, 1.164)	0.505
Self-efficacy for physical activity	**1.376 (1.278, 1.481)**	**<0.001**	**1.377 (1.277, 1.484)**	**<0.001**
Perceived control	1.071 (0.996, 1.151)	0.064	1.059 (0.974, 1.151)	0.177

Table 3.9 *Results from the combined model including all input variables and adjusted for educational attainment*

Psychosocial variable	Odds ratio (95% CI)	p-value
General self-efficacy	0.916 (0.811, 1.035)	0.158
Self-efficacy for physical activity	**1.394 (1.289, 1.506)**	**<0.001**
General perceived control	1.012 (0.925, 1.107)	0.797

These analyses showed that self-efficacy for physical activity was significantly associated with being sufficiently physically active. However, general self-efficacy and perceived control were not significantly associated with physical activity level. None of these three factors interacted with educational attainment in predicting physical activity behaviours.

3.4 Discussion

3.4.1 Research question addressed

This secondary analysis of data collected in SSCCs in Southampton, Gosport and Havant aimed to partially address research question two. *What modifiable factors are associated with diet and physical activity behaviours, and changes to these behaviours in pregnancy?*

3.4.2 Individual factors associated with diet quality and physical activity

Of the factors analysed, general self-efficacy was the only one that was not significantly associated with quality of diet in the individual regression analysis. This result is unexpected as an earlier study with women attending SSCCs in Southampton concluded that general self-efficacy was an important predictor of diet quality, although in that model, the effect was mediated by food involvement and perceived control.[100] In line with the result for diet quality, level of physical activity also showed a non-significant association with general self-efficacy. The general self-efficacy questions asked women about their ability to reach goals and overcome barriers in their lives (**Appendix B**). As self-efficacy was not significantly correlated with diet quality or physical activity, it may suggest that these women did not view their health behaviours as being particularly important. If women did not think that eating a healthy diet or being physically active

was something to strive for, being generally self-efficacious would not correlate with those behaviours. However, behaviour-specific self-efficacy was important in predicting both diet and physical activity. These findings related to self-efficacy agree with the results of a prospective study that examined psychosocial predictors of excessive GWG and found that general self-efficacy was not a significant factor, but that GWG-specific self-efficacy was significantly associated with reduced odds of gaining excessive weight in pregnancy.[219] This suggests that in both pregnant and non-pregnant women of childbearing age, behaviour-specific self-efficacy has a significant influence on diet and physical activity, but that being generally self-efficacious may not be a significant determinant of these behaviours.

While general self-efficacy was not significantly associated with diet quality or physical activity, perceived control was significantly associated with diet quality. This suggests that women who felt that they were in control of their lives and their circumstances ate a better-quality diet, but this sense of control does not appear to have affected the odds of being sufficiently physically active. Literature on the relationship between health behaviours and perceived control in pregnancy is scant[220] and control constructs assessed in these studies are often behaviour-specific. For example, a prospective study examined the influence of habit, intention and perceived behavioural control on diet and physical activity during pregnancy and found that intention and habit, but not perceived behavioural control, were significant predictors of diet and physical activity.[220] However, that study is not directly comparable to the analysis presented in this chapter as perceived behavioural control describes a person's perceived control over the factors that influence their *ability to perform a specific behaviour*[221] and this is not the same as the more general perceived control over one's life measured in the SIH study. In a general population of adults, some studies have found that perceived control is associated with lower mortality risk[222] and lower incidence of cardiovascular disease.[223] Overall, the evidence regarding the relationship between perceived control and diet or physical activity is limited, but the analysis presented here suggests that this construct may be a predictor of diet quality amongst women with young children, so perceived control will be considered for inclusion in the CAS model.

Positive outcome expectancies were significantly associated with diet quality in the SIH cohort, showing that women who believed that there would be positive consequences of eating a healthy diet were more likely to have a better-quality diet. In a trial of an online goal-setting and self-monitoring intervention in pregnancy, engagement with the goal-setting and self-monitoring resources was significantly positively associated with outcome expectancies related to benefitting the baby. However, outcome expectancies related to benefitting the woman's own health were not significantly associated with either goal-setting or self-monitoring.[224] Another study of pregnant women examined dispositional and pregnancy-specific factors and their association with

health behaviours. This study found that women's belief that their behaviours could affect the health of their baby was significantly positively associated with health-promoting behaviours like eating a balanced diet and significantly inversely associated with health-impairing behaviours like drinking caffeine.[225] While the SIH cohort showed that having positive outcome expectancies related to women's own health was a significant predictor of diet quality, studies during pregnancy have shown that outcome expectancies related to the baby's health are also significantly associated with health behaviours, suggesting that this factor is generally important and that pregnancy may provide extra motivation to engage in healthy behaviours.

Social support for purchasing fruit and vegetables was significantly positively associated with diet quality in this group, showing that women whose family members encouraged them to purchase fruit and vegetables were more likely to have better diet quality. Few studies have quantitatively examined the association between social support and health behaviours during pregnancy, but a prospective study used structural equation modelling to do so and found that a latent social support factor significantly predicted fetal growth.[226] This relationship implies that pregnant women with greater social support were encouraged to maintain a healthier lifestyle, which resulted in greater fetal growth, than women who did not have high levels of social support. However, fetal growth is viewed here as a proxy for maternal health behaviours, so findings should be interpreted with caution.

Both measures of food involvement were also significantly positively associated with diet quality across the SIH population, showing that women who gave food greater priority in their lives, and who enjoyed cooking, were also more likely to have a better-quality diet. Other studies of women in Southampton have similarly found that food involvement is significantly positively associated with diet quality,[101,227] although one of these studies found that this association was only significant amongst women of lower educational attainment.[101] Elsewhere, some studies have found that food involvement is associated with a better quality diet amongst UK military personnel,[228] children and parents in the UK,[229] and adolescent boys (but not girls) in Australia.[230] While studies examining the association between food involvement and diet quality during pregnancy have not been published, the existing literature on this construct does suggest that food involvement is a significant predictor of diet quality in general, and should be included in the CAS model.

In the combined regression model, which assessed the association between diet quality and all of the individual factors discussed above, neither social support for purchasing fruit and vegetables nor food involvement was found to be significantly associated with diet. This finding is unexpected as these two constructs (social support for purchasing fruit and vegetables and food

involvement) are explicitly food-related and other studies have suggested that they are associated with diet quality. It is possible, however, that over-adjustment has resulted from producing a combined model. Indeed, it is not uncommon for multiple linear regression models to yield biased results when variables are included that are intermediate variables rather than confounders.[231] Given that the individual regression models were informed by DAGs, which can help to avoid over-adjustement,[213] and that existing literature supports the idea that both social support and food involvement do influence diet quality, they will be considered here to be important factors and will be included in the CAS model.

3.4.3 Educational attainment

In addition to assessing the associations between behaviour and a number of potentially modifiable individual factors, these analyses considered the role of educational attainment in the associations. Steps were taken to determine whether there was an interaction with educational attainment such that the association between the individual variables and diet quality or physical activity changed at different levels of educational attainment. This was done because other studies of a similar cohort in Southampton have suggested that psychological factors such as self-efficacy, sense of control and outcome expectancies are predictive of diet amongst women of lower, but not higher educational attainment.[96,100] However, the analyses presented here did not find any significant interactions between the factors assessed and level of education in predicting diet or physical activity.

It is not clear why the findings from the SIH data differed with regard to the role of educational attainment, but one possible explanation is a difference in women's temporal and environmental context. That is, the survey data presented by Lawrence *et al* were collected in Southampton during the second half of 2007 and the authors suggested that, while psychological factors such as sense of control were important for supporting less educated women to maintain good diet quality, there could be protective environmental factors that helped more educated women to maintain a healthy diet that was less dependent on individual factors.[5] The data for the current study, however, were collected in 2011 in Southampton, Gosport and Havant. Between these two study periods, there was an economic recession and a change in government, both of which may have had an impact on women's health behaviours, regardless of educational attainment. This could have happened through a change in individuals' socioeconomic positions, priorities or psychological factors and there may have also been a detrimental effect on the environmental factors that were hypothesised to be protecting the more educated women in the earlier study. Furthermore, there may be differences between Southampton and Gosport and Havant with regard to the environmental influences on women's diet quality and level of physical activity.

While educational attainment remains an important predictor of diet quality and physical activity level, this study has not found evidence that any of the factors examined are more or less important for women with different levels of education. It should be noted, however, that approximately 65% of participants in this sample had a high level of educational attainment, so it is possible that there was not enough variation in this sample to identify a significant interaction.

3.4.4 Strengths and limitations of this study

As this was a secondary analysis of previously collected data, it was not possible specifically to target women who were pregnant or very recently pregnant. While most of the women in the sample had children aged two years or younger, there were some whose youngest child was considerably older so the study sample may not accurately represent the population of interest. However, all participants were mothers of childbearing age and many of them may have gone on to have more children, representing the inter-pregnancy period.

There are some limitations in the study population which limit the generalisability of its findings. Firstly, approximately 94% of participants were White, while the actual population in Southampton is less than 80% White according to the most recent census.[232] As a result, the study population is not necessarily representative of the Southampton population, and results may not reflect the factors that influence behaviour among other ethnic groups. In addition, although it was anticipated that there would be more women of lower educational attainment and greater deprivation amongst women attending SSCCs, there were more women of higher educational attainment included in the sample. This may suggest that the least educated are less likely to access services such as Sure Start, and that this analysis is not generalizable to the most deprived women in the population.

Women's diet quality was assessed using the 20 item FFQ, which produced a 'prudent diet score.' As described in **Section 3.2.2**, this tool was developed using data from women of childbearing age in Southampton and was highly correlated with a 100-item FFQ.[202] While this tool has been used in a number of epidemiological studies in Southampton, the items included in the questionnaire may limit its generalisability to different population groups or over time. For example, Yorkshire puddings may not be relevant to all ethnic groups and meat-based items may be eaten less frequently due to a rise in the popularity of vegetarianism and veganism.[165] Furthermore, as the FFQ does not yield comprehensive data on consumption or portion sizes, it cannot be used to measure energy so energy-adjusted intake cannot be calculated.[233] However, compared with more detailed methods such as a food diary or 24-hour recall, the interviewer-administered 20-item FFQ causes considerably lower participant burden and was more practical for this study.

Finally, the available data focused on primarily psychological characteristics, which represent only some of the factors that are thought to influence behaviour. Were they available, this analysis would have benefitted from more robust data on such influences as biological and physiological factors, interpersonal relationships, social networks and more detailed information about women's socioeconomic positions. The qualitative study presented in Chapter five will aim to address some of these gaps and contribute to a richer understanding of the factors that influence women's health behaviours.

3.4.5 CAS framework

The individual-level factors that were identified in this chapter have been entered in the CAS model with arrows to represent the observed significant associations. While the correlation matrix in **Section 3.3.2** suggested that many of these individual factors are significantly associated with one-another, these associations were not tested further, and there is not enough information to establish causation. Therefore, no arrows are drawn between individual factors at this point and there is a need to further investigate associations between factors.

All included demographic characteristics; educational attainment, number of children, age and home IMD were significantly associated with diet and physical activity in this study. Demographic factors have been added to the figure as a group rather than entering each of them as an individual factor 1) to avoid producing an overly complicated diagram and 2) because the diagram is intended to guide the design of an intervention and demographic factors cannot be the target of a behaviour change intervention. Furthermore, it is probably more realistic to assume that characteristics such as age and deprivation interact with every part of the system and individual associations cannot reasonably be unpicked.

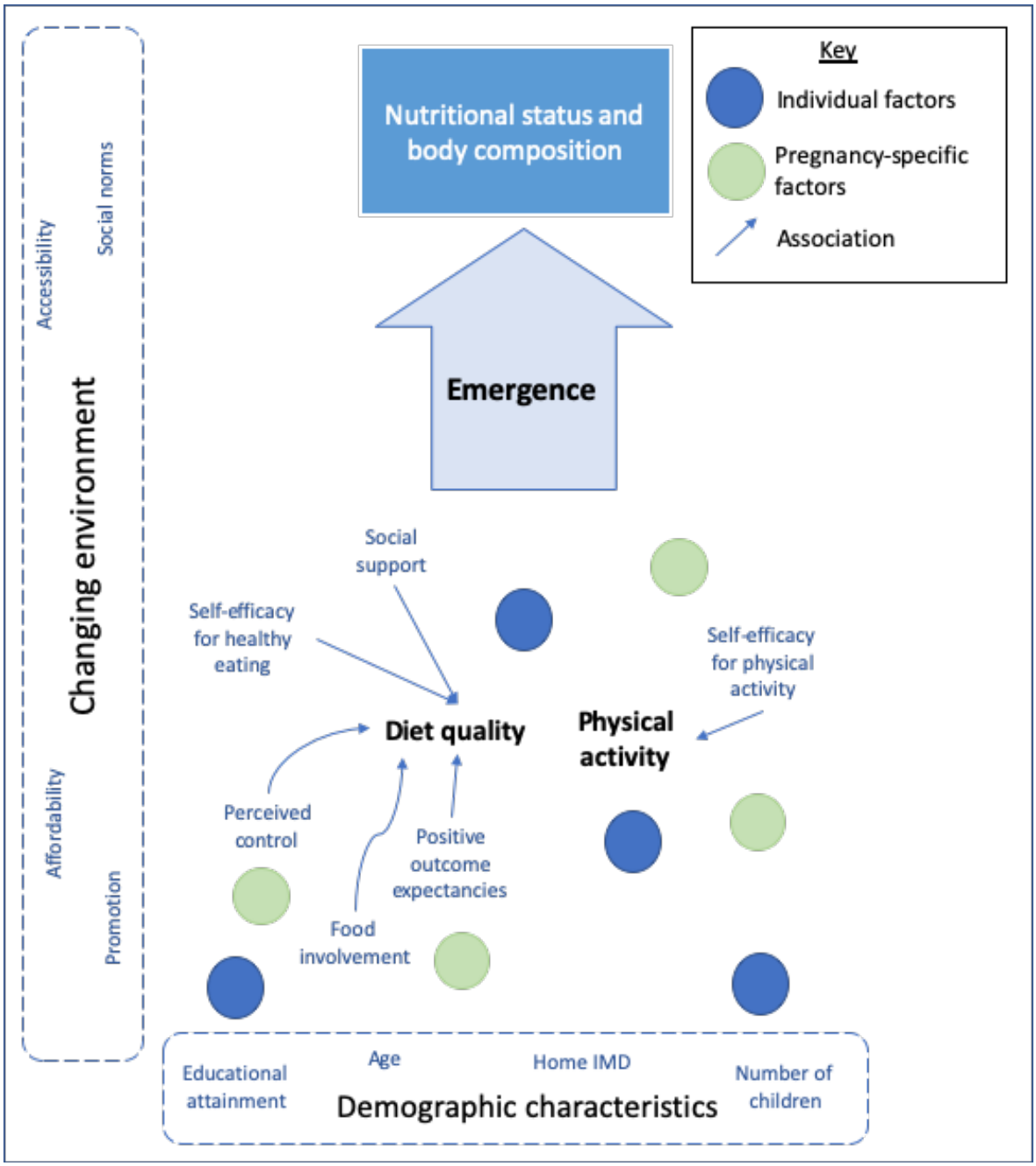


Figure 3.3 *CAS framework with factors identified from survey data added*

3.5 Conclusion

This chapter has shown that, amongst women with young children in Southampton, Gosport and Havant, significant determinants of diet quality are self-efficacy for healthy eating, perceived control, positive outcome expectancies, social support for purchasing fruit and vegetables and food involvement. The only predictor of sufficient physical activity identified here was self-efficacy for physical activity. In most cases, published literature on these constructs and their association with health behaviours has agreed with the findings presented here.

These analyses should be viewed as a first step in developing the CAS model that represents factors that influence diet and physical activity during pregnancy by identifying specific factors that are significantly associated with these behaviours. Further examination of individual-level factors such as those analysed in this chapter is warranted because it is not yet clear whether any of these factors are amenable to change through intervention, or whether changing any of these factors during pregnancy would lead to changes in behaviour. These questions will be addressed through a systematic review in Chapter four. Furthermore, it is clear that the factors influencing health and health behaviours are complex, and go beyond the individual-level factors presented in this chapter. Therefore, it is necessary to explore these wider influences and this will be done through a qualitative study in Chapter five.

Chapter 4 Systematic review of diet and physical activity interventions in pregnancy, and the individual-level factors associated with behaviour change

4.1 Introduction

Chapter three showed that self-efficacy for healthy eating, social support, perceived control, outcome expectancies and food involvement were associated with diet quality, and that self-efficacy for physical activity was associated with greater odds of being sufficiently physically active amongst mothers in Hampshire. This chapter aims to further develop the CAS framework through reviewing the existing literature on behaviour change in pregnancy and i) identifying additional factors that should be included in the framework, ii) exploring which factors may be amenable to change through intervention and iii) determining which factors have been shown to be associated with behaviour change in pregnancy.

Given the recognised importance of nutritional status and body composition during pregnancy, many interventions have been developed to support pregnant women to improve their diet quality and increase their level of physical activity. In turn, a number of systematic reviews and meta-analyses have assessed the effectiveness of such interventions and shown mixed results. For example, a Cochrane review and meta-analysis of diet and physical activity interventions in pregnancy found high-quality evidence that such interventions can significantly reduce the risk of excessive GWG, but the other outcomes; preterm birth, pre-eclampsia, caesarean delivery and macrosomia, were not significantly different between intervention and control groups.[234] Another Cochrane review of dietary advice interventions in pregnancy found very low-quality evidence that suggested a (non-significant) trend towards reducing the incidence of GDM. There was also low-quality evidence that dietary advice interventions may reduce the risk of pregnancy-induced hypertension and GWG, but not pre-eclampsia, caesarean section, induction of labour, perineal trauma, postpartum haemorrhage, postpartum infection or breastfeeding.[235] A systematic review of dietary interventions found that, while some interventions improved diet and others limited GWG, it was difficult to draw useful conclusions due to the variability in methodology and intervention content between studies.[236] There have been many more reviews of lifestyle interventions in pregnancy, and they usually find that such interventions may have a detectable effect on GWG[237-240] or risk of developing GDM,[239,241-243] but little or no effect on any birth or fetal outcomes such as caesarean section or birth weight.[237] This may reflect limitations in existing

studies, which may have been under-powered to detect changes in birth outcomes,[237] or it may suggest that limiting GWG alone is not sufficient to impact significantly on fetal development. Alternatively, given that GWG is associated with measures of offspring health in later life, [39] the finding that reducing GWG does not always result in improved birth outcomes may suggest that birth outcomes are a poor proxy for developmental mechanisms that impact on long-term health.

While there is some evidence to show that lifestyle interventions in pregnancy can have a positive impact on health at least in the short term, there is little consensus as to which intervention components lead to these improvements or how behaviours are changed through intervention. Indeed, most reviews have assessed changes in anthropometric measures[240,244-250] or GDM,[241,251-253] which are affected by multiple factors, so it is difficult to determine which behaviours are influenced by the interventions. Similarly, while observational studies have identified a number of psychological or other individual-level factors associated with health behaviours such as self-efficacy[96,100,254] and social support,[96] it is not clear which of these are amenable to change during pregnancy or how changing any of these factors may lead to a change in behaviour. In order to develop a scalable intervention that supports improvements in diet and physical activity in pregnancy, it would be beneficial to determine which factors are most important to target. Therefore, this systematic review will aim to identify individual-level factors that are associated with changes in diet or physical activity behaviours, and which of these factors are likely to change through intervention.

4.1.1 Review question

Which individual-level factors are associated with changes in diet or physical activity during pregnancy, and which of these are amenable to change through intervention?

4.2 Methods

4.2.1 Study selection

The methods for this systematic review followed guidelines developed by the Centre for Reviews and Dissemination (CRD)[255] and reporting of the review follows guidance set out in the PRISMA statement.[256] Selection criteria (**Table 4.1**) were devised to identify intervention studies that aimed to improve at least one measure of diet or physical activity during pregnancy, and that also analysed at least one modifiable individual-level factor. All intervention trial designs were included except those trials that did not use a comparison group, while observational studies were excluded. Included interventions began in pregnancy and reported at least one measure of diet or physical activity at two or more time points. In addition, at least one modifiable factor that could potentially mediate intervention effects had to be analysed at at least one time point. Interventions that consisted only of providing dietary supplements were not included as supplementation was not considered to represent a change in dietary behaviour. This review aimed to analyse interventions that were designed for a general population of pregnant women, so trials whose participants had a diagnosed medical condition, including mental illness, were excluded. However, given the high prevalence of obesity in the UK, studies that included obese women without any other conditions were considered generalizable to the population and were included. The aim of this review was to inform intervention development in the UK context, and because the factors that influence health behaviours in low- and middle-income countries may be very different from the UK, only trials conducted in high-income countries were included. Due to lack of translation resources, only studies published in English were included. There was no limit on publication date.

Table 4.1 *Systematic review selection criteria*

Inclusion criteria	Exclusion criteria
• Intervention studies including randomised controlled trials, non-randomised controlled trials, and quasi-experimental studies that use a control group • Studies that aim to change behaviour in pregnancy, and may include a post-partum element to maintain these changes • Studies that assess at least one modifiable individual-level factor • Studies of healthy women that begin during pregnancy, including obese women without other conditions • Studies published in English • Studies conducted in high-income countries, as defined by the World Bank • Studies published at any time	• Observational studies • Intervention studies without a control or comparison group. • Studies published in a language other than English • Studies of participants who have a diagnosed illness, including mental illness • Studies that do not assess any modifiable individual-level factors • Studies that do not assess change in at least one measure of diet or physical activity • Studies of interventions that only use a dietary supplement to improve nutritional status

The search strategy was developed in consultation with experts in literature searching. A combination of MeSH (Medical Subject Headings) and free text terms was used to identify interventions that were targeted at pregnant women and aimed to improve diet or increase physical activity. Terms related to the postpartum period were also included as some interventions that begin in pregnancy may measure the primary outcome after birth. Terms related to the individual-level factors associated with behaviour change were not included in the search because preliminary searching showed that inclusion of such terms was too restrictive and greatly reduced the number of results. Therefore, the electronic searches were designed to be as inclusive as possible and studies that did not assess potential mediating factors were removed only in the screening stages. Searches were run in five electronic databases; Medline, Embase, CINAHL, PSYCinfo and Social Sciences Citation Index. All databases were searched from inception through January, 2018. An overview of search terms used is in **Box 3.1**, and the complete search strategy is in **Appendix C.**

Box 3.1 Summary of search terms

Pregnancy/post-partum	Diet
Pregnan*	Diet*
Antenatal	Nutrition
Prenatal	Nutrient
Gestation	Eat
Post-partum	Intake
Postnatal	Consumption
	Food
Intervention studies	Physical activity
Intervention	Physical activit*
Trial	Exercis*
RCT	Sport*
Clinical trial	Fit
	Fitness
	Yoga
	Walk*
	Swim*
	Sedentar*

After removing duplicates, the search resulted in 22,282 publications. All of these titles and abstracts were screened by hand according to the inclusion criteria and 64 were identified as potentially meeting these criteria. Full texts were screened and 53 were excluded because they: did not assess any of the individual-level factors of interest (n=40); did not measure diet or physical activity at two time points (n=8); did not focus on a pregnant population (n=1); included participants with a medical condition (n=1); were not conducted in a high-income country (n=1); or did not use an appropriate study design (n=2). Reference lists of included studies were hand-searched for additional publications that should be included, but this did not result in any more papers. Finally, in May 2018, a cited reference search was conducted in Web of Science to find any publications that had referenced included papers and this process did not identify any additional publications for inclusion. **Figure 4.1** shows this process, which resulted in 11 publications reporting on nine trials.

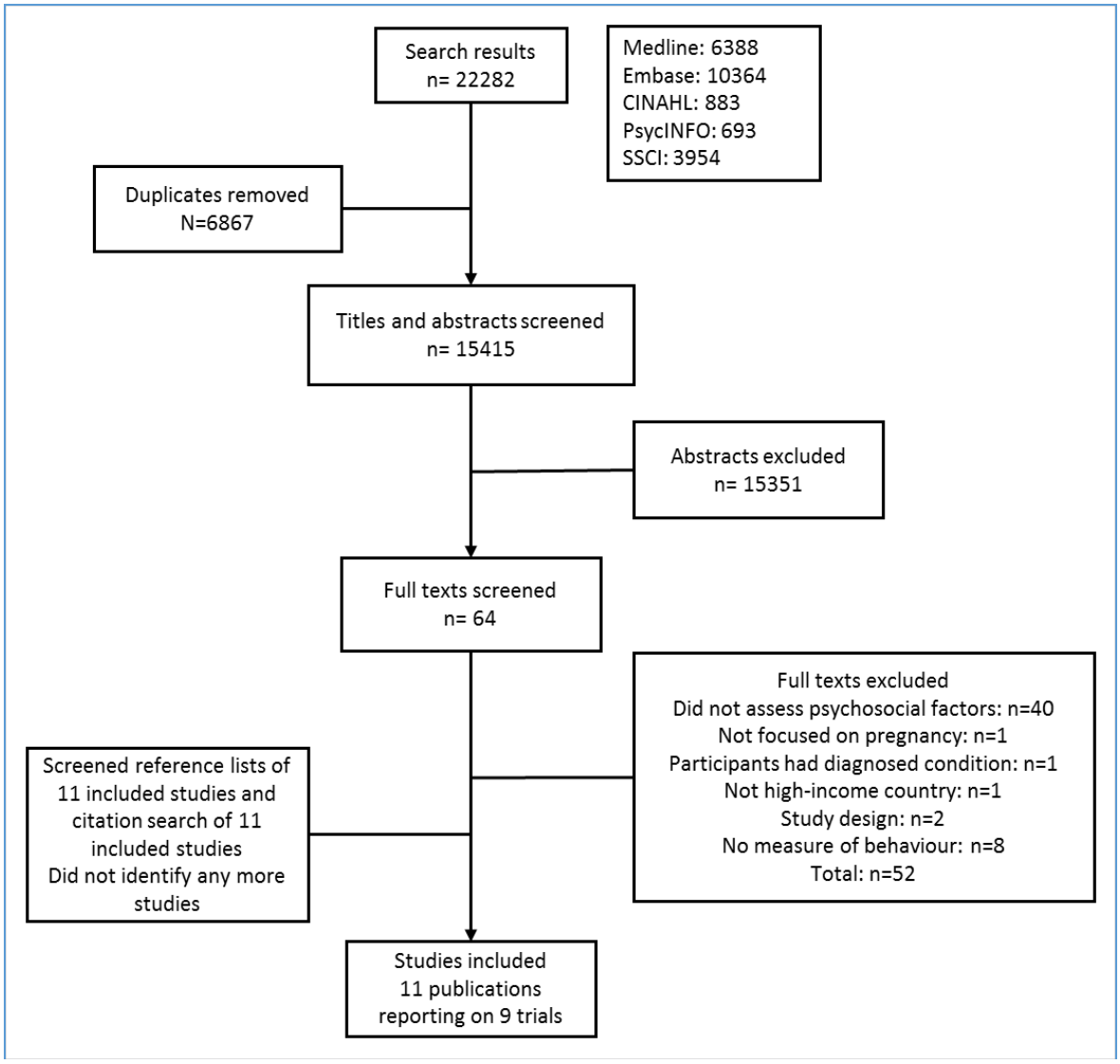


Figure 4.1 *PRISMA flow diagram for systematic review*

4.2.2 Data extraction and quality assessment

Data were extracted from each publication using a data extraction form that was informed by the PRISMA statement[256] and designed to include the key content of each study. This form (**Appendix D**) detailed the intervention, assessment methods, analyses and trial results, and also included a quality assessment table. The assessment of quality used a rubric that was based on the quality assessment criteria described by the CRD,[255] and was piloted ahead of formally conducting the data extraction. The rubric was tailored to this review and was used to assess the potential risk of bias in relation to the review question based on the study design, randomisation, blinding, intervention fidelity, attrition, sample size, outcome measures, statistical analyses, handling of confounding and whether or not intention to treat (ITT) methodology was used. The rubric is shown in **Appendix E**.

4.2.3 Data synthesis

Summary tables were produced describing the characteristics of included studies (**Table 4.2**), their results (**Table 4.3**) and quality assessment (**Table 4.4**). The first table listed summary information about each study including design, intervention, setting, participants, assessment methods and analysis. The second table described extracted results including outcomes for diet, physical activity and individual factors as well as risk of bias rating and overall conclusions. The third table summarised the risk of bias of each study as determined by the quality assessment process. All three tables were organised in the same way, where studies were categorised by type of intervention and within these categories, studies were listed in order of publication date. Once compiled, the data tables were used to examine which factors changed and how these changes were associated with changes in diet or physical activity.

4.3 Results

A total of nine studies (presented in 11 publications) were included in this review; three aimed to improve diet only,[257-260] three aimed to increase physical activity only,[261-263] and three targeted both diet and physical activity.[264-267] Due to the small number of studies assessing these outcomes and the heterogeneity of studies included, a meta-analysis was not feasible. The individual-level factors assessed were knowledge,[257,266,267] perceived barriers,[262,264,265] perceived safety,[263] outcome expectancies,[258,259,263-265] cognitive restraint,[260] dietary disinhibition,[260] confidence,[264,265] action- and coping-planning,[261] intention,[258,259] perceived control,[258,259] self-efficacy[262,263] and social support.[262] Six studies were conducted in the United States, [257-260,262,263,266] one was in Australia,[267] one in Canada[261] and one in the UK.[264,265] The longest follow-up time was 12 months,[260] but most studies had a follow-up time of 12 weeks or less.[257-259,261-263,266,267] Six studies[260,262-267] had similar risk of bias scores ranging from -1 to +3 and these were rated as having a medium risk of bias in relation to the review question. Two studies[258,261] had a score of +6, and were considered low risk, while one study[257] had a high risk of bias with a score of -6. The most common sources of bias were lack of blinding and small sample sizes. Three categories of intervention type were identified: information-only; goal-setting and self-monitoring; and multi-component. **Figure 4.2** shows an overview of the intervention types, target behaviours and outcomes of included studies.

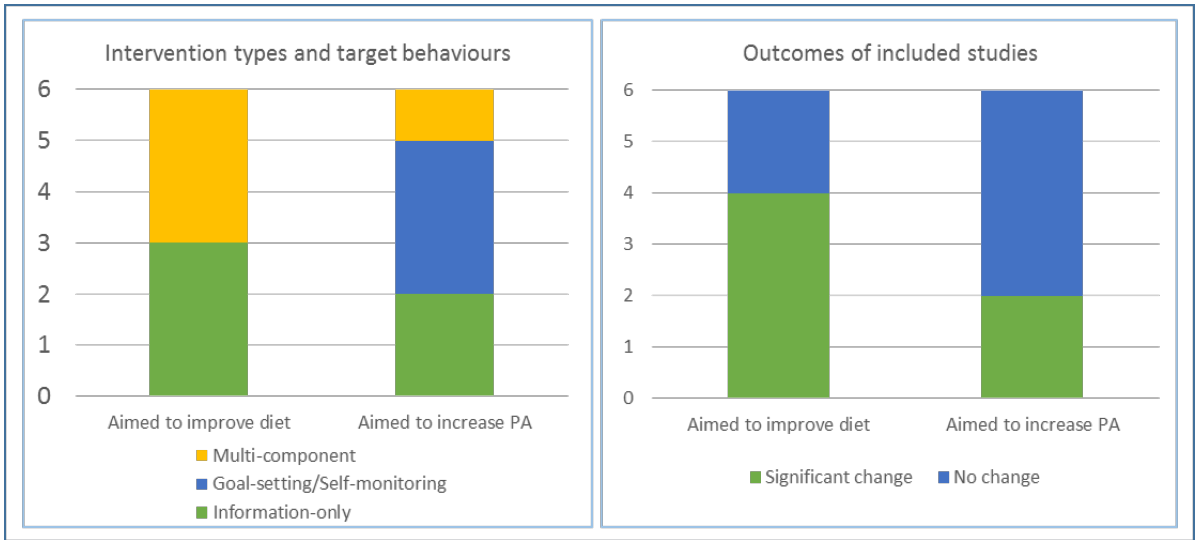


Figure 4.2 *Intervention types and outcomes by target behaviour*

4.3.1 Information-only interventions

All nine interventions provided some information, but in the three oldest studies, providing information was the only intervention component and change in knowledge was the potential mediator assessed. In the Great Beginnings programme, published in 2002,[257] pregnant teenagers attended six weekly informational sessions about nutrition in pregnancy. As a result of the curriculum, participants significantly improved their nutrition knowledge, and while control participants' diet quality got significantly worse over the study period, those who received the intervention maintained a sufficient diet. However, this was the only study rated as having a high risk of bias. The Video Doctor intervention study, which had a medium risk of bias and was published in 2011,[266] provided information that was tailored to individuals' health risk profiles as assessed by a computer programme. After completing the risk assessment in a primary care waiting room, participants viewed videos where an actor 'doctor' gave information and advice. The programme also printed out tailored feedback for participants to discuss with their clinician. Four weeks after the baseline assessment, intervention participants had increased their weight gain knowledge and nutrition knowledge significantly more than the control group, and had also significantly improved their diet and physical activity behaviours. Specifically, they increased their consumption of fruits, vegetables, whole grains and healthy fats, and decreased consumption of sugary foods, refined grains, high fat meats, fried foods, solid fats and fast food. They also increased exercise duration by an average of 28 minutes per week. The control group did not change any behaviours. The third intervention that only provided information was published in 2012, and had a medium risk of bias.[267] Here, participants attended a 60-minute 'healthy start to pregnancy' session in groups of up to 15 women. They completed a screening tool to identify health behaviour risks, and were given information about health behaviours during pregnancy as well as information on behaviour change techniques like setting goals. At 12-week follow-up,

there was no significant difference between groups in GWG knowledge or any measures of diet or physical activity.

4.3.2 Goal-setting and self-monitoring interventions

There were three studies where participants were encouraged and supported to set goals, and these all aimed to increase physical activity. One of these studies included women who were exercising fewer than three times per week at baseline and the intervention consisted of three different sets of PowerPoint slides.[261] In this low risk of bias study, there were two intervention groups and one control group, and all three groups received education about the benefits of exercise in pregnancy. The content of these slides aimed to address constructs key to Protection Motivation Theory including perceived vulnerability, perceived severity, response efficacy and self-efficacy. However, these constructs were not measured. One intervention group received additional slides that encouraged participants to make plans to exercise as well as a planning sheet to form five action plans for exercise over the next week. The other intervention group received this action planning material as well as material that supported them to anticipate potential barriers to exercise and to identify solutions to these barriers. The constructs measured were the extent to which participants felt they had concrete plans to exercise (action-planning), and to overcome barriers if they were to arise (coping-planning). Immediately post-intervention, the two planning intervention groups reported higher levels of action-planning and coping-planning than the group that did not receive planning material. Four weeks post-intervention, both planning groups did more exercise (2-3 more 30-minute bouts of MVPA) as measured by accelerometer than the non-planning group and the combined planning group was doing the most exercise.

The other two goal-setting and self-monitoring interventions were similar in that they were both primarily digital interventions and both encouraged participants to anticipate barriers and identify solutions to potential problems. One of these interventions was delivered via a website that gave participants suggestions based on their current activities and prompted them to set goals and make plans.[263] This study measured self-efficacy, intentions, perceived safety and outcome expectancy in early and late pregnancy as potential mediators of change in self-reported physical activity. In this medium risk of bias study, both the intervention and the control group significantly increased their levels of physical activity from early to late pregnancy and significantly decreased their activity after giving birth, but there was no difference between groups. Self-efficacy was a significant predictor of physical activity after giving birth amongst the whole study population while no other psychological constructs were significant predictors of physical activity levels. Finally, the most recent study included in this review, published in 2016, used a Fitbit to facilitate

self-monitoring.[262] Both the intervention and the control group were given Fitbits and the intervention group also used a mobile phone app, which provided daily prompts, an activity diary, step tracking, tips and videos. At the beginning of the study, participants attended one 30-minute session to discuss physical activity guidelines as well as goal-setting, problem-solving and developing social support. Individual factors assessed were self-efficacy, social support and perceived barriers to physical activity. There were no significant intervention effects on step count or any individual factors except the perception that lack of energy was a barrier. This study had a medium risk of bias.

4.3.3 Multi-component interventions

There were three multi-component interventions that included elements to provide information, self-monitoring, and on-going support. The Fit for Delivery intervention aimed to reduce postpartum weight retention, but was delivered during pregnancy.[260] Intervention components included a face-to-face information session, self-monitoring tools (scales, a food diary and a pedometer), weekly reminder postcards, three phone calls from a dietician and a weight gain chart after each clinic visit. Women who were gaining excessive weight received an additional call every two weeks. Behavioural outcomes included self-reported physical activity and diet quality, and the Eating Inventory[268] was used to measure cognitive restraint and dietary disinhibition. Restraint is a tendency to consciously restrict food intake in order to lose weight or avoid gaining weight while disinhibition is the tendency to overeat in response to stimuli like temptation or stress.[269] The publication that reported the primary outcomes of this trial (GWG and postpartum weight retention) at six months found a significant intervention effect,[270] but there were no significant group x time effects for dietary behaviour or physical activity at any time point. There was no significant effect for dietary disinhibition, but the intervention group significantly increased their cognitive restraint scores compared to the control group through 6 months post-partum. This change was not maintained at 12 months post-partum.

The UPBEAT (UK Pregnancies Better Eating and Activity Trial) pilot study trialled a complex intervention aimed at obese pregnant women and had a medium risk of bias.[264,265] While the UPBEAT full-scale trial[271] was conducted after the pilot, the later study did not report any process or psychometric outcomes, so is not included in this review. Intervention components included a one-to-one appointment with a health trainer and eight weekly group sessions that included education and goal review, an exercise DVD, a pedometer and a log book for tracking weekly SMART goals. The intervention aimed to improve both diet and physical activity and also assessed change in perceived barriers, perceived benefits and confidence. At 28 weeks' gestation, the intervention group showed a significant reduction in total energy, total fat and dietary glycaemic

load, but no changes in physical activity. The authors also reported a significant effect on perceived barriers to both diet and physical activity as a result of this intervention, although they did not provide any details about this outcome or which barriers were measured.

Finally, Healthy MOMs, a complex intervention study that aimed to prevent GDM in pregnant Latina women was published in 2015 and had a low risk of bias.[258,259] The intervention consisted of nine group sessions and two home visits, all conducted in Spanish. The group sessions included education, cooking demonstrations and activities while home visits focused on goal-setting and review. The behavioural outcome was diet quality and the individual-level factors assessed were social support, perceived control and intention to eat healthily. Post-intervention, the intervention group showed a significant improvement in servings of vegetables, total fat, total saturated fat, and percentage calories from solid fat, saturated fat and sugar. Assessment of potential mediating factors showed a significant effect on beliefs about fat, intention to eat vegetables, intention to eat fibre, intention to reduce fat and perceived control regarding fibre. However, mediation analysis concluded that none of these changes in individual-level factors mediated the changes in diet.

Table 4.2 *Summary of included studies*

Authors (year) Country	Trial design	Participants	Intervention	Assessment methods	Analysis
Information only interventions					
Valerie Long, Tamara Martin, Colette Janson-Sand (2002) United States [257]	Non-randomised trial with three comparison groups.	136 pregnant adolescents in the intervention group and three comparison groups C1: Pregnant adolescents not exposed to the intervention C2: Non-pregnant adolescents who were exposed to the intervention C3: Non-pregnant adolescents who were not exposed to the intervention	Great Beginnings: a 6-session nutrition curriculum aimed at the needs of pregnant teenagers. Sessions were delivered weekly.	Assessments were completed at baseline and 6-week follow-up **Diet quality**: 24-hour diet recall **Nutrition knowledge:** 40-question multiple-choice questionnaire about pregnancy-related nutrition knowledge.	ANOVA was used to test for differences in diet quality and nutrition knowledge from baseline to follow-up. Handling of confounding is not mentioned.

Authors (year) Country	Trial design	Participants	Intervention	Assessment methods	Analysis
Rebecca Jackson, Naomi Stotland, Aaron Caughey, Barbara Gerbert (2011) United States [266]	Randomised controlled trial	*Keep Fit* was a sub-study of *Health in Pregnancy (HIP). HIP* provided video counselling about smoking, alcohol and drug use. Women who did not smoke, drink or use drugs were enrolled in *Keep Fit.* Participants were 18 years or older, and less than 26 weeks' gestation. There were 158 participants in the intervention group and 163 in the control group. Most participants were Hispanic or Black and the majority had a university education. The study population were relatively deprived as 85% were on Medicaid. The proportion of participants who were overweight or obese in the intervention and control group was 48% and 41% respectively.	Computer programme where participants filled in a questionnaire immediately before randomisation. Those randomised to intervention received video clips of an actor 'doctor' who provided tailored education on exercise and diet in pregnancy. The programme produced tailored feedback for both patient and clinician so that the clinician could have a conversation about individual risk profile. Finally, the participant received a personalised educational worksheet based on risk profile. Control participants did not receive any feedback or video doctor counselling.	Assessments were conducted at baseline and at least 4 weeks later. Average follow-up time was 6.1 weeks. **Diet:** 18 food frequency items: Servings per week/day of fruits, vegetables, whole grains, fish, nuts, healthy fats, refined flour, high fat meats, solid fats, fried foods, sweets **Exercise:** Two items to assess frequency and duration of PA **Knowledge:** Questions about weight gain, BMI, whole grains, fats, nutrition in pregnancy	T-tests were used to assess change from baseline to follow-up. Intention to treat (ITT) analysis was used, but no details about this are reported

Authors (year) Country	Trial design	Participants	Intervention	Assessment methods	Analysis
Shelley Wilkinson and David McIntyre (2012) Australia [267]	Randomised controlled trial	Women were recruited at ~14 weeks of pregnancy. There were 178 participants in the intervention group and 182 in the control group. Fewer than half of the participants in both groups were educated to degree level while 27.5% in the intervention group and 30.8% in the control group had not completed high school. Most were in paid work. In the intervention group, 43.8% were overweight or obese before pregnancy and this 39.6% were overweight or obese in the control group.	Brief intervention consisting of a Healthy Start to Pregnancy workshop. The sessions ran for 60 minutes and included up to 15 women. Workshops were run by maternity dieticians and had three key components. 1) Screening tool to identify women at risk of not meeting healthy behaviour guidelines 2) Delivery of information and behaviour change strategies, including goal-setting and self-monitoring 3) Signposting to specialist services Both usual care and intervention women received a 12-page booklet about health in pregnancy.	Questionnaires were completed at recruitment (in person) and at 12 weeks post-intervention (postal questionnaire). **Fruit and vegetable intake:** National Nutrition Survey **Diet quality**: Fat and fibre behaviour index **Physical activity:** Active Australia questionnaire **GWG knowledge:** one question about how much weight they should gain in pregnancy	The proportion of women meeting guidelines was calculated at each time point. Chi-square and t tests were used to assess the change in proportion of women meeting guidelines from time 1 to time 2. Means for each group were also calculated, and chi-square and t tests were used to assess the differences between groups, and the changes over time in each group.

Authors (year) Country	Trial design	Participants	Intervention	Assessment methods	Analysis
Goal-setting and self-monitoring interventions					
Gaston and Prapavessis (2012) Canada [261]	Randomised controlled trial with three groups	Pregnant women in Ontario, Canada who exercised fewer than 3 times per week. A total of 60 participants were divided between three groups: PMT only (n=20); Action planning (n=21); and Action planning + Coping planning (n=19). The average age across the three groups was 30 years and all three groups had an average BMI above 26.	There were three different intervention components. One group received protection motivation theory (PMT) material and 12 attention control slides. One group received PMT material, Action planning intervention and 6 attention control slides. One group received PMT material, Action planning intervention and Combined planning intervention. **PMT material:** Power Point slides to educate women about the benefits of exercise during pregnancy. Content aimed to address PMT constructs 'perceived vulnerability,' 'perceived severity,' 'response efficacy' and self-efficacy. **Action planning intervention:** Participants received a planning sheet and were asked to form 5	Data were collected at baseline, immediately, and 4 weeks post-intervention. **Exercise:** Self-report via questionnaire Accelerometer measured exercise for 7 days at each time point. Data were used to produce a weekly activity score. **Action planning and coping planning:** Questionnaires were completed after the intervention session using SurveyMonkey. Action planning: "I already have concrete plans to exercise over the course of the following week" (scale 1-4) Coping planning: "I already have concrete plans regarding what to do if something intervenes in the next week" (Scale 1-4)	Repeated measures ANOVA was used to assess change in physical activity over time between intervention groups. PMT variables were only measured immediately post-intervention, so change in these is not assessed. Differences between groups were measured using ANOVAs with post-hoc tests.

Authors (year) Country	Trial design	Participants	Intervention	Assessment methods	Analysis
			action plans for exercise over the next week **Combined planning intervention:** In addition to action planning intervention, participants were asked to anticipate potential barriers and ways to overcome them.		

Authors (year) Country	Trial design	Participants	Intervention	Assessment methods	Analysis
Hye Kyung Kim, Jeff Niederdeppe, Meredith Graham, Christine Olson, Geri Gay (2015) United States[263]	Randomised controlled trial	A total of 1,077 pregnant women age 18-35 participated. Inclusion: Enrol by 20 weeks gestation, available for 24-month intervention, read and understand English, valid email address Exclusion: Underweight or BMI>35, multiple gestation, history of eating disorder, history of 3+ miscarriages, medical condition that could influence weight change Forty-three percent of participants were overweight or obese, 70% were white and more than half (51%) were educated to degree level or above. At baseline 48% said they were physically active 'Often' or 'Sometimes' while the remaining participants exercised 'Rarely' (28%), 'Hardly ever' (18%) or 'Never' (6%).	Online intervention delivered to two groups: One group received the intervention during pregnancy only, and the other received the intervention during pregnancy and postpartum. There was also a control group that did not receive any additional support. Intervention was a website that included goal-setting and self-monitoring related to diet, physical activity and weight. At baseline, participants reported current activities and were given suggested goals based on responses. They were prompted to set specific and timed goals for physical activity. The website outlined potential barriers and suggested ways of overcoming them before prompting participants to select how they would overcome barriers. They were also asked to	Assessment 1: Between enrolment and 28 weeks gestation Assessment 2: between 32 weeks and 40 weeks gestation Assessment 3: between 6 and 12 weeks after delivery **Physical activity :** Participants reported their frequency of MVPA on a scale of 1-5 at T1 and T2. Possibly also used at T3 (unclear). The Pregnancy Physical activity Questionnaire was also used at T1 and T2 to calculate MET-hours/week. **Intention:** One item "How likely is it that you will engage in 30minutes of moderate-intensity physical activity **Self-efficacy:** 6 questions (1-5 scale) about how sure they were that they would be able to remain physically active, even when faced with	Repeated measures ANOVA was used to assess change in physical activity between time points, and the interaction with intervention group or between demographic groups. Generalized linear models were used to examine the relationships between psychological constructs and changes in behaviour. Mediation analyses conducted based on findings from generalized linear models.

Authors (year) Country	Trial design	Participants	Intervention	Assessment methods	Analysis
			specify how they would like to be rewarded when they met their goals. * It is not clear how long the intervention lasted beyond delivery in the pregnancy/postpartum group.	barriers. Results converted to a n index with mean 3.07 and SD 0.96. Measured at T1 and T2 **Outcome expectancy:** Positive: 3 questions (1-5 scale) about benefits of exercise during pregnancy Negative: 2 questions (1-5 scale) about safety of physical activity in pregnancy. Measured at T1 and T2	

Authors (year) Country	Trial design	Participants	Intervention	Assessment methods	Analysis
JiWon Choi, JiHyeon Lee, Eric Vittinghoff, Yoshimi Fukuoka (2016) United States[262]	Randomised controlled pilot study	Pregnant women in the San Francisco Bay area Inclusion: 18-40 years old, 10-20 weeks' gestation, sedentary lifestyle, intent to be physically active Exclusion: Medical condition that restricts physical activity, current participation in lifestyle modification programme A total of 30 women took part, and were divided evenly between the Intervention (average age 32.9 years) and Control (average age 34.5 years) groups. Most participants were either Asian or white in both groups, and 80% of participants in both groups were educated to degree level or above.	Mobile phone app plus Fitbit. (Control was Fitbit only) One 30-minute face-to-face session where physical activity guidelines were discussed as well as goal-setting, problem-solving skills, techniques for developing social support and a plan for overcoming barriers. Participants were encouraged to increase steps daily to reach 8500 steps/day at least 5 days per week. Participants were asked to self-weigh twice per week. Fitbit displayed steps, distance, flights of stairs, and calories expended. App included daily prompts, daily activity diary, step tracking, tips and videos.	Data collected at baseline and 12 weeks. **Physical activity :** Daily step count (FitBit) **Self-efficacy:** Self-efficacy for Physical activity questionnaire **Social support:** Social support and exercise survey **Barriers:** Barriers to being active quiz	Intervention effect was analysed using ANCOVAs controlling for baseline values. ITT approach was taken.

Authors (year) Country	Trial design	Participants	Intervention	Assessment methods	Analysis
Multi-component interventions					
Suzanne Phelan, Maureen Phipps, Barbara Abrams, Francine Darroch, Kelsey Grantham, Andrew Schaffner, Rena Wing (2014) United States [260]	Randomised controlled trial	A total of 401 women participated, with 200 assigned to the Standard care arm and 201 assigned to the Intervention arm. Participant characteristics were very similar between the two groups; average age was 28 years and the majority of participants were white. Most participants were educated to degree level or above and the average BMI was approximately 26.	Delivered during pregnancy. One face-to-face visit: discussed GWG, physical activity guidelines and healthy eating. Participants were given scales, food diaries and pedometers for self-monitoring Weekly postcards prompting healthy behaviours. After each clinic visit, women were sent a graph of weight gain with feedback. Three brief phone calls from a dietician. Those who were gaining an excessive amount of weight received an additional call every 2 weeks until weight gain normalised.	Data collected at baseline, 30 weeks gestation, 6 months postpartum and 12 months post-partum **Diet:** Block FFQ **Physical activity :** Paffenbarger Physical activity Questionnaire **Cognitive restraint and disinhibition:** The Eating Inventory	Repeated-measures ANOVA used to assess the effects of treatment group and BMI category on changes in diet physical activity, and weight control behaviours.

Authors (year) Country	Trial design	Participants	Intervention	Assessment methods	Analysis
Lucilla Poston, A Briley, S Barr, R Bell, H Croker, K Coxon, H Essex, C Hunt, L Hayes, L Howard, N Khazaezadeh, T Kinnunen, S Nelson, E Oteng-Ntim, S Robson, N Sattar, P Seed, J Wardle, T Sanders, J Sandall (2013)[264] Louise Hayes, C Mcparlin, T Kinnunen, L Poston, S Robson, R Bell (2015) UK [265]	Randomised controlled trial (pilot)	Obese pregnant women Inclusion: BMI ≥30; singleton pregnancy; gestation between 15 and 17 weeks Exclusion: Pre-existing condition or disease; current psychosis A total of 183 women participated with 89 allocated to Control and 94 allocated to Intervention. In the Control group, the majority of participants were aged 31-40 and the average BMI was 36.1. In the Intervention group, slightly fewer than half of participants were aged 31-40 and the average BMI was 36.5.	Participants attended a 1-to-1 appointment with a health trainer, and were invited to weekly group sessions for 8 consecutive weeks (beginning around 19 weeks' gestation). At the initial appointment, women were given a handbook, a pedometer, a log book for weekly SMART goals and a pregnancy exercise DVD. Each group session delivered a different element of the diet and physical activity curriculum. Goals from the previous week were reviewed in each of the weekly sessions.	Data were collected at baseline (15-17 weeks) and at 27, 28, 35, and 36 weeks' gestation. **Diet:** 'Triple pass' 24-hour recall conducted twice (one week apart) at baseline and follow-up **Physical activity :** ActiGraph accelerometer worn for 7 consecutive days. RPAQ also completed **Attitude towards die and physical activity :** Questionnaire about perceived benefits and barriers (not validated)	Linear regressions controlling for baseline value

Authors (year) Country	Trial design	Participants	Intervention	Assessment methods	Analysis
Edith Kieffer, Diana Welmerink, Brandy Sinco, Kathleen Welch, Erin Rees Clayton, Christina Schumann, Virginia Uhley (2014)[258] AND Megha Shah, Edith Kieffer, Hwajung, Kristina Schumann, Michele Heisler (2015) United States[259]	Randomised controlled trial	Low-income pregnant Latinas Eligible if aged 18 or over, less than 20 weeks pregnant, resident in southwest Detroit. There were 139 participants in each of two groups: Intervention and Control. The average age in both groups was 27. In the Intervention group, the average BMI was 24.2 and 39% of participants were overweight or obese. In the Control group, the average BMI was 24.7 and 39% were overweight or obese.	Healthy MOMs Intervention consisted of 9 group meetings (15-20 women) and two home visits. 11 week intervention period Intervention delivered in Spanish Group sessions covered information about eating more fruits, vegetables and fibre, and eating less fat and sugar. Sessions included activities and cooking demonstrations. In home visits, women were encouraged to set and review diet goals. Graduation ceremonies followed programme completion. Control participants had three educational sessions about pregnancy, birth and infant care.	Questionnaires were completed at baseline and immediately following the final session. **Diet:** FFQ validated in a Hispanic population. Baseline FFQ asked about diet over the last year. Follow-up FFQ asked about diet over the last 3 months. **Social support:** Questions on 1-5 scale "How often has your Husband of Partner/ Mother/ Friend or Others encouraged you to eat more fruits and vegetables/ eat foods with less fat/ eat foods and drink beverages with less sugar/eat more fibre." **Perceived control:** 1-5 scale "I can easily eat more fruits and vegetables/ eat foods with less fat/ eat foods and drink beverages with less sugar/ more fibre." **Intention to eat healthy:** 1-5 scale	Consumption of each nutrient was analysed using a linear mixed model in which baseline and follow-up values were included as the outcomes, with dummy variables for time and group and their interaction included as predictors. ITT analysis included all available data from all participants. Model was adjusted for maternal age, education level, years lived in the US, care at federally qualified health centre, food stamp participation, WIC enrolment, parity, pre-pregnancy BMI and English-speaking ability. Moderator analysis: Identified possible moderators using linear regression models with effects for intervention group, moderator and interaction between the two. Also,

Authors (year) Country	Trial design	Participants	Intervention	Assessment methods	Analysis
				about plans to eat 5 FV per day/ eat foods and drink beverages low in sugar/ low in fat/ eat high fibre foods every day **Healthy food beliefs:** 1-5 scale about health benefits of eating healthy. "I will have a healthier pregnancy if I eat at least 5 FV every day/ eat foods that are low in fat/ eat high fibre foods every day" and "I won't gain enough weight unless I eat foods and drink beverages that contain a lot of sugar"	dichotomised variables into two groups and compared outcomes between groups. Mediation analysis: Sobel-Goldman mediation test to assess whether intervention effects were mediated by potential mediators.

Table 4.3 *Outcomes of included studies*

First author (year)	Main results	Risk of bias	Conclusions
Information only interventions			
Long (2002)[257]	**Diet** Diet quality remained constant in the intervention group, but declined significantly in the control group. In the intervention group, average baseline caloric intake was 2,743 kcal and 2,592 kcal at follow-up. In the control group, average baseline caloric intake was 2,325 kcal and 1,962 at follow-up. Similarly, average daily protein intake stayed stable in the intervention group (101 g a baseline and 102 g at follow-up). In the control group, there was a considerable decrease in protein intake (103 g at baseline ad 86 g at follow-up)	High risk	The intervention group increased in nutrition knowledge significantly more than the control group. The intervention group maintained a sufficient diet while the control group declined in diet quality over the 6-week trial period.
	Nutrition knowledge Nutrition knowledge increased more in the intervention group than the control group, and this difference in change was significant. Intervention group increased from an average score of 23 to 31. Control group increased from average score of 20 to 24.		

First author (year)	Main results	Risk of bias	Conclusions
Jackson (2011)[266]	**Diet and exercise** Healthy food intake Compared to the control group, the Video Doctor group significantly increased their intake of: fruit and vegetables per day from 3.0 to 3.44 servings; whole grains per day from 2.6 to 3.28 servings; percent whole grains from 43% to 42.1%; and fish, avocado and nuts per week from 4.6 to 5.25 servings. There was no significant change in intake of vegetable oil. Unhealthy food intake Compared to the control group, the Video Doctor group significantly decreased their intake of fried foods per week from 2.6 to 1.94 servings and solid fats per week from 2.1 to 1.52 servings. There was no significant change in: sugary foods per day; refined grains per day; high ft meats per week; or fast food per week. Exercise The Video Doctor group significantly increased their average physical activity from 127 minutes per week to 155 minutes per week. However, the difference between groups at follow-up was not significant (p=0.42). **Nutrition and weight gain knowledge** Of 17 questions, the Video Doctor group significantly increased their knowledge from an average of 11 questions correct at baseline to 12.5 questions at follow-up. The control group also significantly increased their knowledge from 11.3 questions correct at baseline to 12 questions at follow-up. However, the difference between groups at follow-up was significant (p=0.009), showing that the Video Doctor group increased their knowledge significantly more than the control group.	Medium risk	The intervention group showed a significant increase in many healthy foods and significant decrease in unhealthy foods while the control group did not change their diet quality. The intervention group also increased physical activity significantly while the control group did not. Both groups improved in grain and fat knowledge, but there was a significant difference between groups in total knowledge and knowledge about fat at 4-week follow-up.

First author (year)	Main results	Risk of bias	Conclusions
Wilkinson (2012)[267]	**Diet and physical activity (results from ITT analysis)** The only outcome that was significantly different between groups was the percentage of women meeting guidelines for fruit consumption, which decreased less in the intervention group than the usual care group. In the intervention group, 8.5% of women were meeting guidelines for fruit consumption at T1 and this decreased to 7.3% at T2. In the usual care group, the percentage of women meeting guidelines for fruit consumption decreased from 9.9% to 4.4%. The P value for the difference between groups over time was 0.009). There was no significant change in any of the other outcomes: percentage of participants meeting recommendations for vegetable consumption; percentage of participants meeting recommendations for physical activity; average servings of fruit per day; average servings of vegetables per day; overall diet quality; or weekly minutes of physical activity.	Medium risk	Compared with the usual care group, the intervention group had significantly fewer women decrease their fruit consumption below pregnancy guidelines. However, there was no significant difference between groups in increased servings of fruit per day. There were no other significant differences between groups over time. This intervention did not increase knowledge or improve any health behaviours.
	GWG knowledge At baseline none of the participants in either group answered the question about appropriate weight gain correctly. At follow-up, 2 participants in each group answered the question correctly.		
Goal-setting and self-monitoring interventions			
Gaston (2012)[261]	**Physical activity** Results for physical activity are presented in figures only and the outcomes are: self-reported leisure time physical activity; objectively measured 30-minute bouts of MVPA; and objectively measured total physical activity. The results show that all measures of physical activity increased from Time 1 to Time 2, but decreased from Time 2 to Time 3. At Time 3, the 'combined planning' group was significantly more physically active than the other two groups, according to all three outcome measures. The 'PMT-only' group was the least active.	Low risk	This study did not measure the effect of the PMT material. They measured planning constructs at one time point, and assumed that post-intervention differences between groups would represent intervention effectiveness. All groups increased exercise from baseline to time 2, but decreased from time 2 to time 3. However, both planning groups remained significantly more active than the PMT only group at time 3 (4 weeks post-intervention).
	Action planning and coping planning When action planning and coping planning were measured, the 'combined planning' group had significantly higher scores in both outcomes (p=0.001). The 'PMT-only' group had the lowest scores.		

First author (year)	Main results	Risk of bias	Conclusions
Kim (2015)[263]	**Physical activity** The table in the paper is not well-presented and it is not clear what columns represent. The whole cohort showed a significant increase in physical activity from T1 to T2, and significant decrease at T3. There was no significant effect by intervention condition.	Medium risk	Although not well-reported, this study found that self-efficacy significantly predicted higher levels of physical activity post-partum, even when controlling for intentions. When controlling for intentions, there were no other significant predictors of physical activity. There were no differences in physical activity between groups.
	Psychological constructs Self-efficacy and perceived safety (but not positive outcome expectancies) at baseline were associated with higher exercise intentions at T2. When controlling for intentions, there were no significant predictors of physical activity at T2. Self-efficacy was a significant predictor of physical activity at T3, even when controlling for intentions (=0.001).		
Choi (2016)[262]	**Physical activity** There were differences between groups in step count, but they were not significant at any time point. This may be due to small sample size.	Medium risk	There was no significant effect on step count, but there appears to have been a significant effect on the perception of lack of energy as a barrier to physical activity in pregnancy.
	Psychosocial constructs Of all of the perceived barriers measured, lack of energy was the only one that significantly decreased in the intervention group, and not the control group (p=0.06) from baseline to 12-week follow-up. The remaining perceived barriers did not significantly change in the intervention group (in comparison with the control group). These were: lack of time; social influence; lack of willpower; lack of resources; and social support. Self-efficacy was also assessed, and did not significant change from baseline to follow-up.		

First author (year)	Main results	Risk of bias	Conclusions
Multi-component interventions			
Phelan (2014)[260]	**Diet** There was no significant group x time interaction for any dietary behaviour. Physical activity is reported in terms of kilocalories per day. There was a non-significant group x time interaction (p=0.06).	Medium risk	This intervention did not significantly change any outcomes at 12 months postpartum.
	Dietary disinhibition and cognitive restraint There was no significant group x time interaction for dietary disinhibition Cognitive restraint scores increased more in the intervention group than in the control group during pregnancy (p=0.04) and through 6 months postpartum (p=0.051), but not at 12 months postpartum (p=0.28).		
Poston (2013)[264] AND Hayes (2015)[265]	**Diet and physical activity** Compared to the control group, the intervention group saw significant changes in total energy, dietary glycaemic load, protein as percent of energy intake and fata as a percent of energy intake. The change from baseline to follow up, with 95% confidence interval, is shown for each of these outcomes below. Total energy (MJ/d): -0.94 (-1.72 to -0.28) Dietary GL (g/d): 33 (-47 to -20) Protein (%E): 1.5 (0.1 to 2.8) Total fat (%E): -3.2 (-5.6 to -0.8) Total protein in grams per day did not significantly change. There were no significant changes in physical activity, as measured by accelerometer.	Medium risk	There were significant improvements in measures of diet and reduced perceived barriers to both diet and physical activity. There were no significant changes to physical activity as a result of this intervention. Analysis of 36 week data are presented in paper Hayes (2015). However, most of the analyses examine change over time in the whole cohort – not divided by intervention/control.
	Barriers and perceived benefits Compared to the control group, the intervention group showed a significant reduction in perceived barriers to both diet and physical activity. There was no significant treatment effect on perceived benefits or confidence to improve diet or physical activity.		

First author (year)	Main results	Risk of bias	Conclusions
Kieffer(2014)[258] AND Shah (2015)[259]	**Diet** Only results from unadjusted model are presented, but the authors state that findings did not change when adjusted for covariates. There was a significant treatment effect observed for a number of dietary outcomes, which are summarised below. The only outcomes that did not show a significant treatment effect were total calories and servings of fruit. <u>Outcomes with significant treatment effect and 95% confidence interval</u> Vegetable servings: 41.9 (19.2, 68.8) Fibre (g): 15.9 (3.1, 30.3) Added sugar (g): -16.1 (-29.6, -0.1) Total fat (g): -12.9 (-22.0, -2.7) Total saturated fat (g): -15.7 (-25.2, -5.0) Percentage total calories from solid fats and added sugars: -9.4 (-14.3, -4.3) Percentage of total calories from saturated fat: -1.1 (-1.7, -0.5)	Low risk	This intervention resulted in significant changes in a number of dietary behaviours. Younger women, and women with higher levels of spousal support and perceived control responded better to the intervention. However, the intervention effects were not mediated by increase in perceived control, intentions, or healthy food beliefs.
	Potential mediators/moderators <u>Moderators</u> Added sugar reduced significantly in younger women (age 18-29), but not older women. Higher baseline spousal support was associated with higher increase in fruit and vegetable consumption. Baseline perceived control was negatively associated with decreased fat consumption. <u>Mediators</u> No significant mediators were detected, but various hypothesised mediators significantly changed from baseline to follow-up. Factors that significantly changed in the intervention group compared to the control group were: healthy food beliefs about fat; intention to eat vegetables; intention to eat fibre; and intention to reduce total fat. Factors that did not significantly change in the intervention group compared to the control group were: healthy food beliefs about vegetables; healthy food beliefs about fibre; healthy food beliefs about sugar; intention to reduce added sugar; and all measures of perceived control.		

Table 4.4 *Quality assessment summary*

First author (year)	Study design	Randomisation	Blinding	Intervention fidelity	Attrition	Sample size	Outcome measures	Analysis	Confounding	ITT	Total
Long (2002)[257]	0	-1	-1	0	-1	-1	-1	+1	-1	-1	-6
Jackson (2011)[266]	+1	+1	-1	+1	0	-1	-1	-1	-1	+1	-1
Wilkinson (2012)[267]	+1	+1	-1	0	-1	+1	0	-1	+1	+1	+2
Gaston (2012)[261]	0	+1	0	0	+1	+1	+1	0	+1	+1	+6
Kim (2015)[263]	+1	0	-1	+1	-1	0	0	+1	+1	-1	+1
Choi (2016)[262]	+1	0	-1	+1	+1	-1	+1	+1	-1	+1	+3
Phelan (2014)[260]	+1	+1	-1	0	0	-1	0	+1	+1	+1	+3
Poston (2013)[264] AND Hayes (2015)[265]	+1	+1	-1	0	0	-1	+1	+1	+1	0	+3
Kieffer(2014)[258] AND Shah (2015)[259]	+1	+1	0	0	0	+1	0	+1	+1	+1	+6

4.3.4 Associations between individual-level factors and behaviour

While eight of the nine studies reported individual-level factors at two time points, none reported associations between behaviour change and change in these factors. There was one study that only measured self-efficacy at one time point, and while the intervention did not have any effect on physical activity, baseline self-efficacy was associated with higher levels of physical activity at follow-up.[263] Two studies reported the findings of mediation analyses. The Healthy MOMs study showed that none of the changes in intention or beliefs mediated any changes in behaviour.[258,259] The intervention study that used a website for online goal-setting and self-monitoring found that self-efficacy, but not outcome expectancy or perceived safety, significantly mediated intervention effects on physical activity in pregnancy and early postpartum.[263] Aside from these results, it is only possible to summarise which factors were changed through intervention and whether any diet or physical activity behaviours also changed. Changes in all outcomes are summarised in **Table 4.5**.

Knowledge

Studies that assessed knowledge were all assessing information-only interventions and in the two studies where knowledge increased (Great Beginnings and 'Video Doctor'), diet[257] and/or PA[257,266] also improved. In the trial of 'Healthy Start to Pregnancy,' knowledge did not change, and there was similarly no effect on diet.[267]

Outcome expectancies

Outcome expectancies were assessed in three studies, which all used different terms ('perceived benefits,' 'healthy food beliefs,' and 'outcome expectancies') to represent expected consequences of exercising or eating a healthy diet. The UPBEAT pilot study did not find any changes in perceived benefits to healthy eating or to exercise and while there was a significant improvement in diet, there were no changes in physical activity.[264,265] Healthy MOMs found that the food beliefs score related to reducing fat intake increased significantly compared to the control group while there was no difference between groups in beliefs regarding the consequences of consuming vegetables, fibre or added sugar. This study also found a significant improvement in diet.[258,259] The web-based goal-setting and self-monitoring intervention found that outcome expectancies significantly declined through the intervention period, but this factor was not a significant predictor of physical activity.[263]

Perceived barriers

Perceived barriers were reported in two studies. In the UPBEAT pilot study,[264,265] there were significant changes in perceived barriers to both diet and physical activity and there were also

significant improvements in diet. Physical activity did not change. In the trial that used a Fitbit, only one of five perceived barriers, lack of energy, changed significantly and there was no change in physical activity.[262]

Planning

Although the Healthy MOMs study[258,259] reported outcomes for 'intention,' this was measured by explicitly asking participants about their *plans* to eat a healthy diet, so it is considered here to represent planning rather than intention. Therefore, planning was measured in two studies and both of these studies resulted in an improvement in behaviour. The intervention that used PowerPoint and worksheets to encourage planning significantly increased action planning and coping planning, and there was also a significant increase in total physical activity.[261] Healthy MOMs found an increase in planning to eat healthily as well as a significant improvement in diet, although mediation analysis showed that the change in this factor did not mediate the improvement in diet.[258,259]

Intention

In the study that used online feedback and goal-setting, intention was hypothesised to predict behaviour, and this was measured with a single item about the likelihood of doing 30 minutes of exercise five days per week.[263] This showed a significant decline from early to late pregnancy, but higher levels of intention at each time point were significantly positively associated with subsequent levels of physical activity.

Other factors

The remaining factors were not significantly changed and each was only reported in one study. These were self-efficacy,[262] confidence,[264,265] perceived control,[258,259] social support,[262] cognitive restraint[260] and dietary disinhibition.[260]

Table 4.5 Summary of trial outcomes

Outcome	Long (2002)[257]	Jackson (2011)[266]	Wilkinson (2012)[267]	Gaston (2012)[261]	Kim (2015)[263]	Choi (2016)[262]	Phelan (2014)[260]	Poston (2013)[264] Hayes (2015)[265]	Kieffer(2014)[258] Shah (2015)[259]
Diet									
Physical activity									
Knowledge									
Outcome expectancies									
Perceived barriers									
Planning									
Intention									
Self-efficacy									
Confidence									
Perceived control									
Social support									
Cognitive restraint									
Dietary disinhibition									

Key:

	Significant change
	Some significant changes
	No change

4.4 Discussion

This systematic review of intervention studies aimed to identify individual-level factors that were associated with changes in diet or physical activity during pregnancy, and which of these factors were amenable to change through intervention. It should be noted that half of included studies did not find any significant changes in behaviour so there is limited scope to assess which factors are associated with changes in diet and/or physical activity. Two of the six studies that aimed to increase physical activity, and four of the six studies that aimed to improve diet, achieved a significant change and none of the studies showed a change that was maintained beyond four weeks post-intervention. However, some individual-level factors were successfully changed in the included studies, and some of these studies also resulted in a short-term, but significant change in behaviour.

4.4.1 Individual factors assessed

Knowledge

Of the three intervention studies that aimed to increase pregnancy-specific knowledge by providing information,[257,266,267] two resulted in a significant change in knowledge. The Great Beginnings Programme provided a nutrition curriculum for pregnant teenagers and found a significant increase in nutrition knowledge as well as a significant improvement in diet quality.[257] The Keep Fit programme provided information through a 'Video Doctor' and this resulted in significant improvements in both diet and physical activity, as well as a significant improvement in knowledge about fat.[266] These results suggest that interventions that successfully increase knowledge can have a significant impact on diet and physical activity during pregnancy. While providing information is not generally considered to be sufficient to change behaviour,[272] it is possible that pregnancy represents a unique period where increasing knowledge may be effective. This could be the case because some women are not aware of pregnancy-specific guidelines for diet and physical activity, but want to meet these guidelines once they learn about them.

The association between knowledge and diet or physical activity during pregnancy has not been examined extensively and most of the literature is observational. For example, a cross-sectional study of low-income pregnant women in America assessed a number of biological, psychological and social factors that may influence infant birth weight. In this small study (N=55), a regression model that included maternal age, pre-pregnancy BMI, nutrition knowledge and gestational age

at birth explained 52% of the variance in birth weight.[273] Number of children, perceived health competency, income, educational attainment and nutritional adequacy were not significant predictors of birth weight in this study. Another study that measured both knowledge and health behaviours during pregnancy found that almost all (92%) participants knew that their diets would affect the health of their babies and most (69%) knew that 30 minutes of physical activity per day were recommended.[274] However, less than half of participants were aware of how many servings of fruit (8%) and vegetables (35%) were recommended per day. This study also found that most women did not meet the guidelines for fruit or vegetable consumption or for physical activity. In this study, associations between knowledge and behaviour were not analysed, though, so inferences about the role of knowledge in predicting health behaviours cannot be drawn.

Outcome expectancies

Findings for outcome expectancies were inconsistent. Healthy MOMs, aimed at pregnant Latinas,[258,259] found an increase in healthy food beliefs and also found an improvement in diet while the UPBEAT[264,265] pilot study did not find a change in perceived benefits and showed an improvement in diet, but no change in physical activity. One of the online goal-setting interventions found that, while positive outcome expectancies decreased over the study period, this decrease was not associated with participants' level of physical activity.[263] From these mixed findings, conclusions about the association between outcome expectancies and diet or physical activity cannot be drawn. One reason for this may be that each study that measured outcome expectancies used a different term and a different scale, meaning that findings are not directly comparable.

In the literature, the association between outcome expectancies and lifestyle during pregnancy is not well-described. A prospective study that examined the psychosocial determinants of online self-regulatory activity during pregnancy found that outcome expectancies related to the effect on the baby's health were significantly positively associated with online goal-setting and self-monitoring for diet and physical activity, while outcome expectancies related to the woman's own health were not.[224] This study aimed to prevent excessive GWG, and whilst engagement with intervention features was assessed, diet and physical activity behaviours were not measured. However, its findings suggest that making women aware of the potential impact of their health behaviours on the development of their offspring could motivate them to improve their diet quality or increase levels of physical activity. In the current review, the studies that assessed outcome expectancies did not specify whether the expected consequences of improving diet or increasing physical activity were focused on the woman's own health or the health of the baby. Further research into these associations during pregnancy has not yet been done, but the question could be addressed in future intervention trials.

Planning

Planning was targeted, and significantly increased, by two interventions. One of these studies, which provided action-planning and coping-planning tools, significantly increased total physical activity.[30] The other, which was a multi-component intervention targeted at pregnant Latinas, significantly improved diet quality. [27,28] This suggests that encouraging women to make plans can support behaviour change, but there is limited evidence as only two studies reported this factor.

Other factors

For the remaining individual-level factors (perceived barriers, perceived safety, cognitive restraint, dietary disinhibition, confidence, perceived control, self-efficacy and social support), there were no consistent findings. Therefore, there is not enough evidence to draw conclusions about whether they are amenable to change through intervention, or whether such a change would lead to a change in behaviour. Given the observed associations between some of these factors and health behaviours discussed both in Chapter three and in the Introduction to this chapter, it may be valuable for ongoing and future intervention studies to assess factors associated with health behaviours such as self-efficacy, perceived barriers, confidence and intention at baseline and follow-up and ascertain i) if they can be changed through intervention, and ii) whether such changes are associated with changes in behaviour.

4.4.2 Strengths and limitations

This review followed standard guidance described by the CRD[255] and PRISMA.[256] The literature search was comprehensive in that five databases were searched and a combination of MeSH and free text terms captured a variety of intervention studies with diet and physical activity outcome measures that were consistent with the review questions. A source of bias in many systematic reviews is publication bias, which results from the fact that studies with positive findings are more likely to be published than studies that do not show an effect. For this review, only published studies were included, but consultation with experts did not reveal any unpublished works that should be added. The search strategy intentionally omitted terms related to individual-level factors so as not to limit search results, and instead this screening was done by hand. The search was also strengthened by screening reference lists of all included studies and performing a cited reference search, although these strategies did not result in any additional publications. Data extraction was rigorous and used a data extraction form that was tailored to this review and piloted. Similarly, quality criteria were clearly defined from the beginning, so the quality assessment process was consistent and transparent. However, the rigour of the review was

limited by the fact that the process was undertaken by a single researcher. The CRD guidance recommends that two reviewers undertake the data extraction and quality assessment independently,[255] but it was not considered pragmatic to use a second reviewer for the purposes of this thesis.

There was a relatively small number of studies included in this review, and there was considerable heterogeneity between them. While there were primarily three types of intervention that all aimed to improve diet and/or physical activity during pregnancy, studies varied in terms of intervention content, measurement tools, measures of effect size and which factors were assessed. The heterogeneity of studies meant that meta-analysis was not feasible and few conclusions could be drawn. However, a detailed narrative synthesis was carried out that allowed some trends to be identified.

While most of the included studies were randomised controlled trials, only two were rated as having a low risk of bias. The most common source of bias was lack of blinding so it is possible that participants' and assessors' knowledge of treatment allocation affected study outcomes and led to an increased possibility of type I error. Another common source of bias was small sample sizes as most studies did not report a power calculation and one study had as few as 30 participants. Therefore, it is likely that many studies were under-powered to detect a change in the outcomes of interest, increasing the probability of type II error. While lack of statistical power can often be overcome through meta-analysis, this was not possible in this review for the reasons stated above.

4.4.3 Implications

This review suggests that knowledge can be changed through intervention during pregnancy, and that interventions that increase pregnancy-specific diet or physical activity knowledge may also produce a change in behaviour. Planning to be healthier was also associated with improvements in behaviour, although this was only assessed in two studies.

The factors identified in this chapter differ from those shown to predict diet and/or physical activity in Chapter 3 so further conclusions cannot be drawn about whether self-efficacy, social support, food involvement, perceived control or outcome expectancies are amenable to change. This also shows that further research is needed to ascertain whether these factors should be targeted by behaviour change interventions as existing evidence is extremely limited. Future trials that aim to improve diet or increase physical activity by targeting these individual factors should measure them pre- and post-intervention. In addition, alternative methods such as qualitative are needed to gain a more in-depth understanding of the factors that influence women's behaviours

during pregnancy and whether or not they are modifiable. The next chapter will address these questions through qualitative methods.

4.4.4 CAS framework

This systematic review has identified two individual-level factors that were successfully changed through interventions that also resulted in a significant change in behaviour; knowledge and planning. The three trials that aimed to increase knowledge were all providing pregnancy-specific information about diet and/or physical activity, so knowledge of pregnancy-related guidelines is being added to the CAS framework as a pregnancy-specific factor. Women who had plans to make a change and to overcome potential barriers changed their behaviours in two studies, so planning has also been added to the model. As both of these factors improved in included studies, it is inferred that they are amenable to change through intervention. In the model below, evidence of amenability to change is indicated with a box drawn around each factor (**Figure 4.3**).

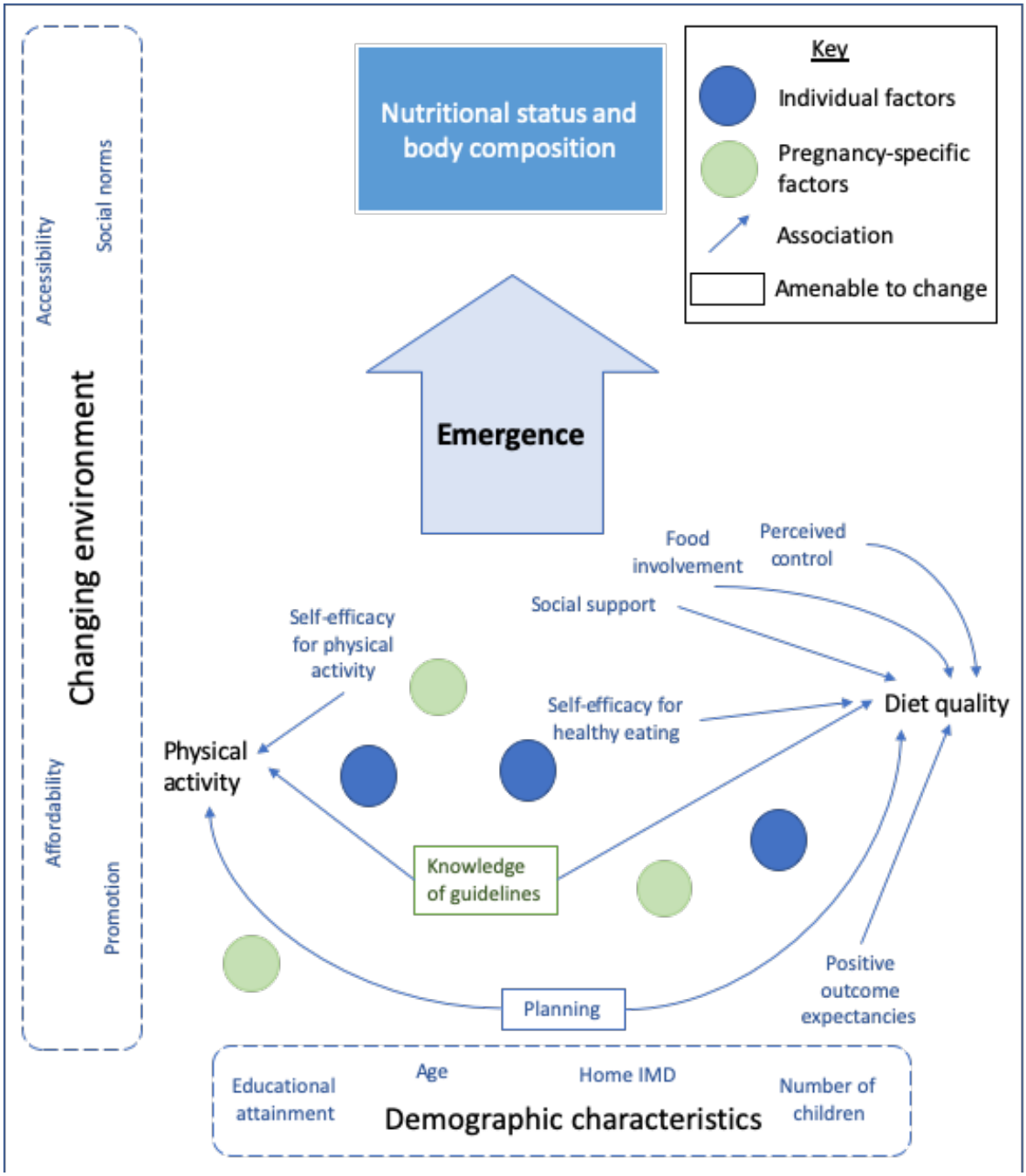


Figure 4.3 *CAS framework with factors from systematic review added*

Chapter 5 Qualitative study to explore factors that influence diet and physical activity during pregnancy

5.1 Introduction

Chapters three and four used quantitative data to identify factors that were associated with women's diet and physical activity behaviours. In Chapter three, this was done through statistical analyses of questionnaire data and in Chapter four, quantitative findings from existing studies were reviewed and synthesised. As a result, behaviour-specific self-efficacy, social support, perceived control, food involvement and positive outcome expectancies have been identified as being associated with diet and physical activity and knowledge and planning have been shown to be amenable to change. However, as can been seen in Chapter four, many intervention trials result in non-significant or small, short-term effects.[267,275-277] One factor that may help to explain these results is lack of engagement amongst some participants as studies have reported considerable variation in engagement such that participants who engage with the intervention experience a significant benefit, such as lower GWG, compared to those who do not engage.[275] Quantitative research does not aim to explore individual differences and experiences, so the studies presented in Chapters three and four cannot provide a comprehensive understanding of the system of factors that influence diet and physical activity in pregnancy. Rather, qualitative research is required to gain a deeper understanding of factors that are important in women's lives, which may or may not be measurable. In order to best inform the development of the CAS model, and subsequently the development of more effective interventions, a qualitative study comprising interviews and focus groups (FGs) was conducted with recently pregnant and currently pregnant women, respectively.

The data presented in this chapter were collected from two groups of women. First, one-to-one interviews were conducted with women who had recently completed the Southampton PRegnancy Intervention for the Next Generation (SPRING) trial. Next, FGs were conducted with pregnant women attending an antenatal class called Preparation for Birth and Beyond (PBB). These two study populations are described below.

5.1.1 Southampton PRegnancy Intervention for the Next Generation (SPRING)

SPRING is a randomised controlled trial (RCT) currently running in Southampton whose participants are pregnant women planning to give birth at the local maternity hospital.[278] Using a

2^2 factorial design, SPRING is testing the effects of vitamin D supplementation in pregnancy on the bone health of babies, as well as the efficacy of support from research nurses trained in Healthy Conversation Skills (HCS) in improving the participants' health behaviours.

HCS has been used in various contexts, and could be an effective intervention to support women to make a change during pregnancy. This is a set of skills for health and social care practitioners designed to support behaviour change by encouraging reflection on the changes people want to make.[279] HCS training was developed in collaboration with local health services in Southampton, UK and by using these skills, healthcare practitioners aim to encourage patients to reflect on their health behaviours and empower them to find their own solutions to overcome barriers to change.[20] This is facilitated through conversations with patients that are driven by open discovery questions, beginning with 'how' or 'what,' encouraging patients to reflect on the changes they would like to make, and on their personal circumstances. HCS-trained practitioners listen rather than give advice, and facilitate the setting of health goals and SMARTER plans; plans that are Specific, Measurable, Action-oriented, Realistic, Timed, Evaluated and Reviewed.[198,278] The key skills are summarised in **Box 5.1** below.

Box 5.1 *Key Healthy Conversation Skills*[279]

Healthy Conversations Skills: Five key skills

1. Identify and create opportunities to hold healthy conversations
2. Ask Open Discovery Questions to help someone explore an issue
3. Spend more time listening than giving information or making suggestions
4. Reflect on practice and conversations
5. Support someone to make a SMARTER plan

The use of these skills is being trialled for its effectiveness in supporting improvements in health behaviours of pregnant women as part of the SPRING trial.[278] Women are randomised to one of four groups: placebo pill and normal care; vitamin D supplement and normal care; placebo pill and HCS support; vitamin D supplement and HCS support (**Figure 5.1**). The provision of vitamin D supplements is double-blinded and treatment allocation will not be un-blinded until the end of the trial. Half of the participants are randomised to receive HCS support; these women are seen by HCS-trained research nurses at each of the four study visits and receive one phone call from an HCS-trained nurse during the trial. Women who are randomised to receive normal care are seen by research nurses who have not been trained in HCS, but the participants attend the same number of study visits and receive a phone call at the same time as women in the HCS groups. The research team could not be blinded to HCS treatment allocation, but participants are not told that they are receiving the lifestyle support intervention and they are generally unaware that this is an additional element to the study.

In the SPRING study visits with women allocated to the HCS intervention arm, HCS-trained nurses have a healthy conversation with women about their health and lifestyle in pregnancy. Nurses ask open discovery questions to encourage participants to set a health-related goal and to make a SMARTER plan to achieve their goal. At each study appointment, the nurse revisits the conversation, encourages reflection and supports women to try to achieve their goals. In study visits with women who are randomised to receive normal care, nurses do not prompt women to reflect on their lifestyle or set any health goals. All participants receive a phone call at 26 weeks' gestation to check on how they are finding the study and remind them of their next appointment. For HCS-allocated participants, the nurse will ask about their goals and have a healthy conversation over the phone. The trial design summary for SPRING is shown in **Figure 5.1**.

For the current study, women who had been in the HCS intervention arms (both groups who received support from HCS-trained nurses) and had completed the SPRING trial were invited to take part in an additional follow-up interview about their experiences talking to the nurses about their lifestyle in pregnancy. The purpose of these interviews was to characterise the health behaviours of pregnant women and determine which behaviours changed in pregnancy. Alongside this, the aim was to understand the sources of support that women found useful in maintaining a healthy lifestyle, the resources they felt would have benefitted them, and the role the research nurse support played in this. Finally, the postnatal period was discussed including how they had maintained any changes, further plans and goals for a healthy lifestyle, and sources of support that were present or absent once regular contact with healthcare professionals had ceased.

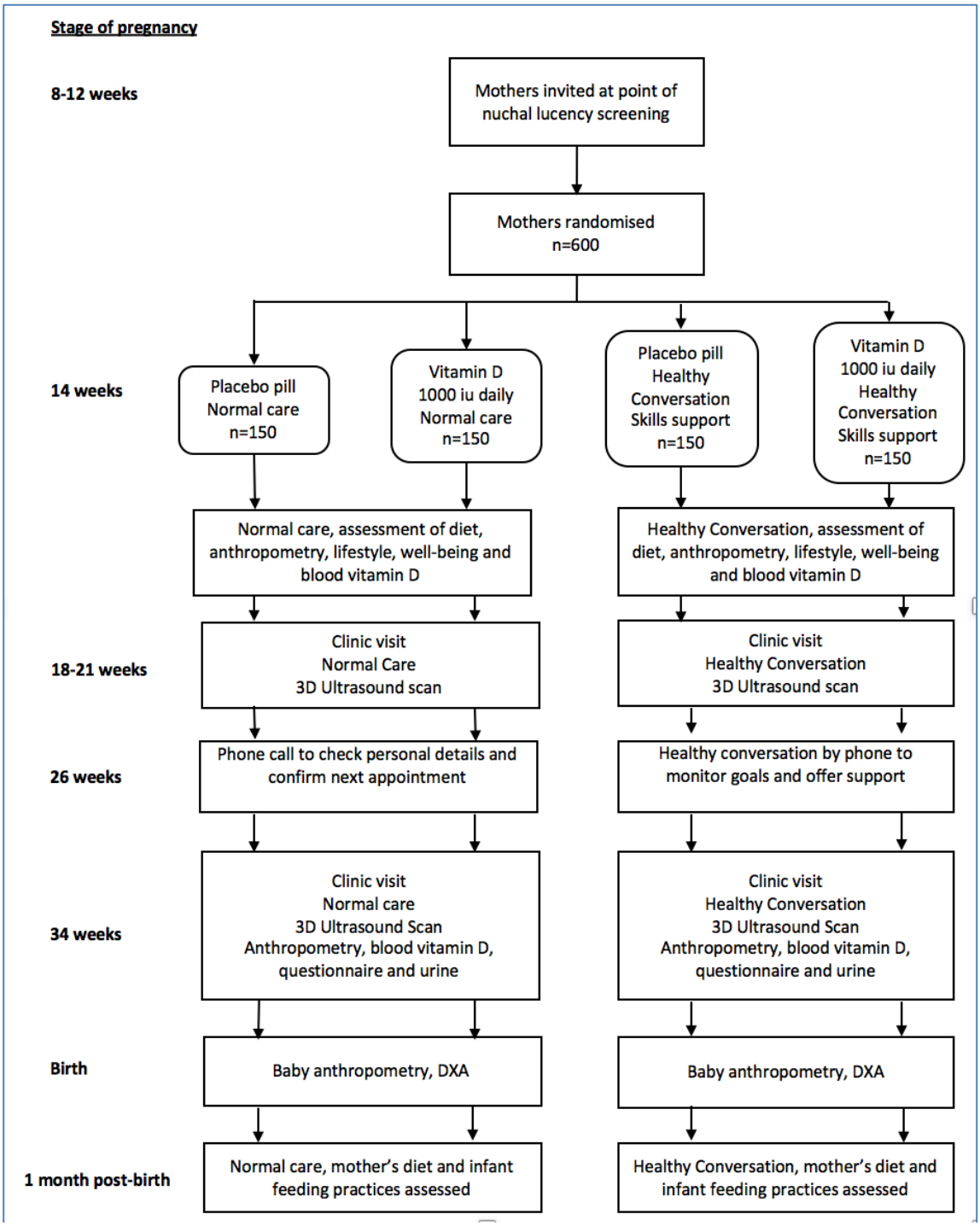


Figure 5.1 *SPRING flow diagram*[278]

5.1.2 SPRING participants

The one-to-one interviews presented in this chapter were conducted with a sample of women who had recently completed the SPRING study. All of these women lived in Southampton, which is home to a varied population as described in Chapter one. However, the women who took part in SPRING were generally highly educated, and the majority lived in areas of the city that were amongst the 50% less deprived in England. Most women in SPRING were in their first or second

pregnancy. The demographic characteristics of women who took part in SPRING up to the date of the last interview for this interview study are presented in **Table 5.1.**

Table 5.1 *Characteristics of the women who took part in SPRING up to the date of the last interview*

Variable	Number of participants (n=274)
Age at interview	
19-25	33
26-30	68
31-35	97
36-40	67
41-45	9
Number of other children*	
0	104
1	107
2	46
>2	10
Level of education	
GCSE/O levels or lower	40
A levels	80
Higher National Diploma	12
Degree or above	142
Home index of deprivation quintile⁺	
1	30
2	51
3	79
4	48
5	64
Ethnicity	
White	259
Black	4
Indian	2
Bangladeshi	1
Other Asian	3
Other/Mixed	5

*Data missing for seven participants
⁺Data missing for two participants

5.1.3 Preparation for Birth and Beyond

In order to collect data from women who were currently pregnant, and to increase the diversity of the sample of participants, two FGs were conducted with women attending PBB; an all-day antenatal class in Southampton. This is an NHS midwife-delivered service that is free for pregnant women and their partners to attend.[280] Women attend this class when they are approximately 30-36 weeks pregnant, and topics including labour, giving birth and caring for an infant are discussed.

5.1.4 Research questions

This chapter aims to supplement the findings from Chapters three and four by using qualitative data to gain a richer understanding of the factors that influence women's health behaviours in pregnancy, and how this may vary between individuals. Research questions one and two are addressed.

Research question one: *How can we support women during pregnancy to improve their diet and physical activity behaviours?*

Research question two: *What modifiable factors are associated with diet and physical activity, and changes to these behaviours, in pregnancy?*

5.2 Methodology

5.2.1 Qualitative research

Quantitative research is part of a long-standing tradition in the medical and allied health fields of seeking out an objective and universal truth. Qualitative research, on the other hand, can complement this positivist worldview and aims to learn from individuals' perspectives and experiences.[281,282] Taking a more relativist view allows for the consideration of differences between people's experiences, preferences and contexts, and does not expect to find an 'answer' that applies to everyone. In addition, by asking open questions rather than being confined by a rigid structure, qualitative researchers can collect a wide range of views beyond those that would have been predicted or captured using quantitative methods. For these reasons, a qualitative study was conducted to build on the quantitative analyses already presented. The aim was to explore participants' perspectives in order to gain a deeper understanding of women's lifestyles during pregnancy, the differences in their experiences and their views of behaviour change support interventions during pregnancy including HCS.

5.2.2 Philosophical approach

Before conducting a qualitative study, it is necessary to make explicit the philosophical position of the researcher. This is especially important in a thematic analysis as this approach is not dependent on a specific philosophy, but can be used across a range of epistemologies.[283] This means that the epistemological position in conducting this study must be clearly stated as it will have influenced how the interview guide was developed, how the interviews were conducted, how the data were coded, how the analysis meetings with the research team were steered and finally how the findings were written-up.[283,284]

Epistemology describes the way knowledge is produced, and influences the way research is conducted.[284,285] In the context of this study, epistemology refers to the way conclusions are drawn about women's lifestyles in pregnancy, the factors that affect their health behaviours, and their experiences with lifestyle support resources. At one extreme, a constructivist epistemology posits that the truth, or reality, is not something that can be objectively learned or discovered. Rather, knowledge is produced through interactions between researchers and participants, and is therefore unique to these interactions. While probably more commensurate with a relativist ontology; a belief that truth is relative and a single reality does not exist, it is possible to hold simultaneously a constructivist epistemology and a realist ontology.[286] In other words, it is possible to believe that the 'truth' does exist, but also believe that understanding of this truth is limited by what can be learned through interpersonal actions and human experience.[286] Constructivism would suggest that the knowledge about women's lifestyles in pregnancy that resulted from the interviews will have been produced from these interactions, and interviews conducted by a different researcher or with different participants would not produce the same knowledge.[285]

While findings from qualitative research are inevitably coloured by the interactions between researchers and study participants, the view that knowledge is a product of research and not something that can be observed, learned, or generalised to some extent seems to limit its utility in practical applications. Rather, the perspective adopted herein is best described as critical realism; a philosophy that describes an ontological and epistemological position.[287] Critical realism stands in contrast to both the constructivist view that reality is a product of human understanding and interpretation, and the realist view that truth is an entity that really exists and can potentially be wholly understood through empirical research. Critical realism does not define reality in terms of human understanding, but rather that "there is a real social world we can attempt to understand or access through philosophy and science, but some knowledge can be closer to reality than other knowledge," (pg. 182).[287] Reality is presented as existing at three levels: the empirical level describes experiences and observations; the actual level describes events that occur, whether they are observed or not; the real level describes the causal mechanisms that lead to events at the other two levels. The three levels are understood to interact, and researchers attempt to gain knowledge of all three levels, but the potential to understand these is bound by the limits of human observation.[287]

Adopting a critical realist position is conducive to the CAS approach that underlies this thesis. A CAS approach assumes that there are a number of factors interacting with one another to make up a system, and the system results in emergent properties: nutritional status and body composition in this case. The individual interactions that make up this system cannot always be

known and are not always predictable, but through observation, analysis and critical reasoning, we can gain some understanding about the nature of this real system. Roughly, the three levels of reality as proposed in critical realism can be mapped against characteristics of a CAS. Firstly, the 'empirical,' or observed level is comparable to the emergent properties of the system. Secondly, the 'actual' level that contains events that may not be observed, provides a parallel to the processes that lead to changes in behaviour. These could be thought processes, goal-setting, planning or decision-making. Finally, the 'real' level describes causal relationships that lead to events at the other levels, which may or may not be observed. These can be thought of as interactions between the factors that interact in a CAS. The conceptual relationship between the levels of a critical realist position and the CAS perspective is shown below in **Figure 5.2.**

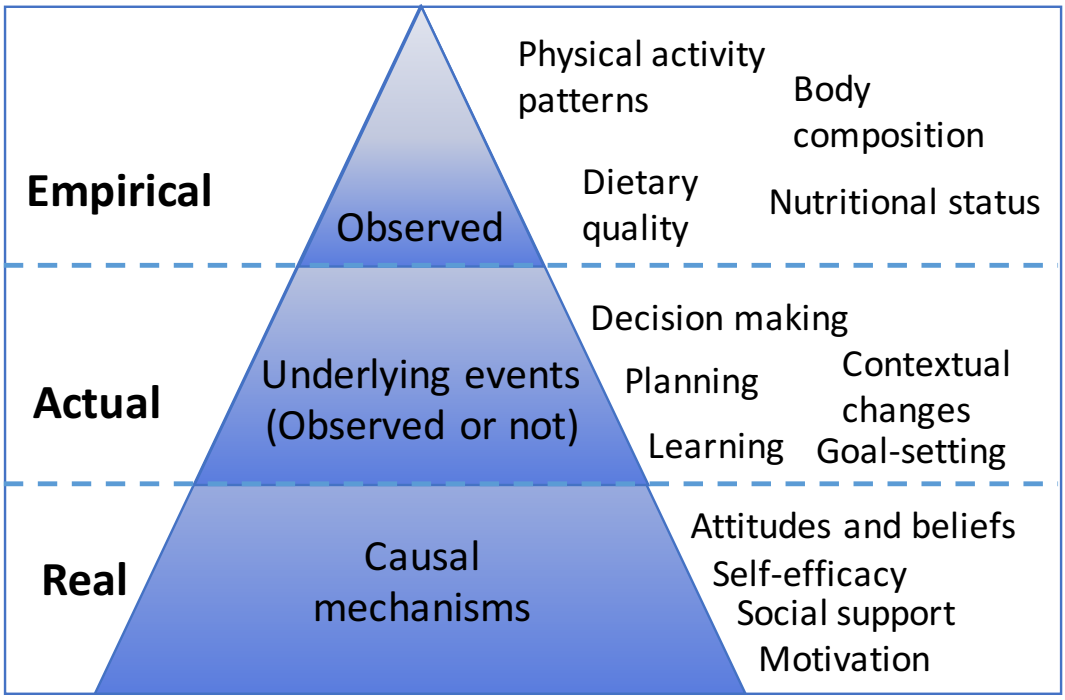


Figure 5.2 *The levels of reality proposed by critical realism are related to the properties of a CAS framework*

5.2.3 Thematic analysis

There are many methods for analysing qualitative data, which may be more or less appropriate depending on the epistemological position of the researcher, the content of the dataset, the target audience, the intended application of the research and the research question(s) being addressed.[282] Common approaches include grounded theory,[282,283,288] discourse analysis, phenomenology, and ethnography, which follow clearly defined steps and are grounded in specific philosophies.[289] An approach that is relatively flexible and more accessible than many others is thematic analysis because it is not limited to a specific philosophy, is useful for developing real-world application of the research, and does not require "deep theoretical commitments."[282] Braun and Clarke described this process in 2006, suggesting that thematic

analysis should be considered a methodology in its own right rather than simply a method used as a part of other processes.[283]

Thematic analysis was selected as the most appropriate approach for the purposes of this thesis. As noted above, flexibility in approach as well as philosophy is one of the key advantages of thematic analysis over many other qualitative methods.[283] Because of this, the research team are not limited to a rigid analysis 'recipe' and can make decisions about the analysis process that are best suited to the data and to the research question. However, lack of an adequate framework could limit the rigour of the study, potentially leading to an 'anything goes' approach. Therefore, the six steps laid out by Braun and Clarke (2006)[283] were used to guide this analysis, and are described in the Methods section below.

Thematic analysis is also flexible in that it can be done either inductively or deductively.[283] For this study, analysis was done inductively so as to yield as rich and complete an analysis as possible. By taking a data-driven rather than theory-driven approach, new codes were produced as they were identified in the interview transcripts. This allowed for the consideration and inclusion of ideas that may not have been identified if themes were pre-selected based on the research questions.

5.2.4 Rigour

In qualitative research, it is inevitable that the researcher's assumptions and perspectives will impact on the conduct and analysis of the study.[281,283-285] It is necessary to make these beliefs explicit so that the researcher can reflect on the potential effects on the research, and so that the reader has enough information to appraise the work adequately. In taking a critical realist approach instead of a constructivist approach, I do not expect my worldview to construct the knowledge gained from this interview study, but rather I aim to make it explicit, regularly reflect on my biases, and limit their impact on my findings as much as possible. Therefore, reflection and consultation with the research team were involved in every step of the Methods.

5.3 Methods

5.3.1 Interview participant recruitment

Participants for one-to-one interviews were recruited opportunistically from women who had taken part in the SPRING trial.[278] Women who completed the trial in the HCS intervention arm were sent an invitation letter (**Appendix F**) and information sheet (**Appendix G**) by post within six months of their one-month follow-up SPRING visit. The letters were followed by phone calls and/or text messages in order to maximise participation. All women who expressed an interest either by phone or email received an immediate response and an interview in their home was arranged. Invitation letters were sent out in batches to participants until enough interviews were conducted to reach saturation;[290] this was once the interviewer and observer agreed that no new ideas were being introduced, resulting in a total of 17 interviews. The target sample size was also limited by the number of women available within the time-frame of the study.

5.3.2 Focus group participant recruitment

FGs were conducted during the lunch break in PBB classes and lunch was provided for all participants to maximise recruitment. As part of a separate research project, partners attending the classes were invited to take part in a different focus group in a different room. Dates for the FGs were selected in advance and information sheets (**Appendix I**) were mailed to couples who were booked in the class on those days. Before beginning the class, participants were reminded that they had received the information sheet and given a duplicate copy so that they had sufficient time to decide whether they wanted to take part. Those who did not want to take part in the FG left the room for lunch while women who were willing to take part stayed in the room with the FG moderator.

5.3.3 Discussion guide development

For the one-to-one interviews, a semi-structured discussion guide (**Appendix H**) was developed to allow the interviewer to tailor questions to explore each participant's views and experiences. A series of open questions was compiled in consultation with members of the research team, based on previous work. All questions were written as exploratory open discovery questions, beginning with 'what' or 'how' in order to encourage participants to give detailed answers rather than yes/no or one-word answers. The discussion guide was updated as more interviews were completed to reflect topics that emerged as important to participants.

The FGs were planned and conducted after the interviews, and the final interview discussion guide informed the development of the FG discussion guide (**Appendix K**). The approach taken was very similar, except that the FG questions centred more on women's attitudes towards their own health in pregnancy and the routine services available as they had not taken part in SPRING or had exposure to HCS.

5.3.4 Interviews

Qualitative interviews can be conducted in a number of different ways, based on how open or structured they are. A very open interview, or 'informal conversational' interview does not use prescribed questions, but rather aims to gain insight from a relaxed, organic conversation. A very structured interview, or 'standardised open-ended' interview requires all questions to be prescribed and asked in exactly the same way in each interview. A style that lay between these two extremes is a 'general interview guide approach.'[291] This approach uses a set of pre-determined questions to guide the interview, but the order of the questions and the way in which they are worded can change. The potential disadvantage of this approach is that participants may not respond in the same way to a question that is worded differently and a flexible approach may mean that individual interviews will have different emphases and address questions more or less thoroughly.[291,292] The strengths of this approach are that the openness allows the interviewer to ask follow-up or probing questions in a conversational way and the structure means that all points on the interview guide will be addressed. For this study, the 'general interview guide' approach was taken so that the interviewer could ask probing questions where appropriate, and all sections of the topic guide were covered to some extent in each interview.

Face-to-face interviews in each woman's home were conducted by one researcher (TR) and supported by one of two observers (WL for the first two and SS the other 15) between July 2016 and February 2017. Having received the information sheet in advance, participants gave written consent at the time of the interview and were also asked for verbal and written consent for audio recording. Participants were reminded that they were free to end the interview and/or withdraw from the study at any time without giving a reason. All interviews began with the question, 'What does it mean to you to have a healthy pregnancy?' and thenceforth loosely followed the semi-structured discussion guide. The role of the observer was to listen to the interview, following along with the discussion guide. At the end of each interview, the observer was invited by the interviewer to ask questions to explore any areas felt not to be adequately addressed, or seek elaboration of any points that seemed important or interesting during the interview.

5.3.5 Focus groups

FGs involve a relatively unstructured discussion between participants that is guided by a moderator, and are distinct from one-to-one interviews because of the group interaction that takes place.[293,294] This should result in a more natural social situation than an interview as participants engage in a group conversation about a topic in which they all share an interest.[293-295] By encouraging group discussion, participants may feel more supported by their peers,[295] more comfortable using their everyday vernacular[294] and less pressured to give socially desirable responses.[295] By involving multiple participants at once, FGs also present an opportunity to elicit unexpected knowledge and to collect a wide range of sometimes contradictory views, yielding a rich and potentially novel dataset.[293] Given these advantages, the FGs were run in a way that aimed to encourage relaxed group discussion. Participants were first given lunch, and asked to complete the consent form and demographic questionnaire (**Appendix J**). Once seated, the moderator briefly re-iterated the purpose of the FG, reminded participants that they were free to leave the room at any time, and encouraged them to speak to each other. The moderator loosely followed the discussion guide, while allowing the group to dictate the pace and direction of the conversation as much as possible. Due to the recruitment methods used, the duration of the FGs depended on the time allotted for lunch, which was approximately 30-40 minutes.

5.3.6 Data analysis

The one-to-one interview data were collected and analysed first. Audio-recordings were transcribed verbatim and analysed thematically using NVivo (QSR International) software. This process was done inductively, following the guidelines set out by Braun and Clarke (2006).[283] Firstly, familiarisation with the dataset was done through conducting the interviews, transcribing them and reading through each completed transcript at least once. Initial codes were developed by creating 'nodes' in NVivo as new topics arose in the transcripts. Some codes were broad, such as 'diet' while others were narrower, such as 'use of digital interventions.' Where a section of text fitted into more than one code, it was categorised under all appropriate codes. After all transcripts had been coded this way, nodes were organised into themes and sub-themes. Six of the 17 transcripts were double-coded, with three coded by each of two experienced qualitative researchers (WL and CV) using the themes and sub-themes that had been developed. After the process of coding and double-coding was complete, the research team met to discuss the themes, how they represented the data and how best to name and organise them into a coding frame.

Thematic analysis is appropriate for FGs as well as interviews, and in both cases the aim is to search for repeated patterns across the dataset.[283] When the FGs were completed, the audio-recordings were transcribed verbatim and coded thematically. As with the interviews, familiarity

with the data was achieved through conducting and transcribing and FGs and re-reading the transcripts. FGs were coded inductively, assigning existing codes from the coding frame to some sections of text and adding new codes as required by the data. This process resulted in an amended coding frame, which was again discussed and finalised with the research team. Where appropriate, similarities and differences between interview data and FG data were examined.

5.3.7 Ethics approval

For this interview study, right of access was received from University Hospital Southampton Foundation Trust (UHSFT) Research and Development (R&D) and the substantial amendment to the SPRING protocol to include these interviews was approved by the South Central – Hampshire B Research Ethics Committee. All patient-facing materials including the consent forms, invitation letters, demographic questionnaire and information sheets were submitted and received ethics approval before recruiting to interviews or FGs. The SPRING study received approval from the Medicines and Healthcare products Regulatory Agency (MHRA), Southampton and South West Hampshire Research Ethics Committee and from UHSFT R&D.[278]

5.4 Results

5.4.1 Characteristics of study participants

Interview participants

A total of 17 women were interviewed within six months of their one-month follow-up SPRING visit and all lived in the Southampton area (**Table 5.2**). All participants had completed A-levels and most were educated to degree level or above. Home index of multiple deprivation (IMD) by Lower-layer Super Output Area (LSOA), as defined by the Department For Communities and Local Government,[296] ranged from the most deprived to the least deprived quintile, but most participants (9/17) were within the 40% least deprived. Ages ranged from 23 to 40 years (mean age at interview date was 33 years).

Focus group participants

Five pregnant women took part in each of two FGs (n=10). All of these women were in their first pregnancy, and they were slightly younger (mean age was 30 years) than the women who took part in the interviews. While 16 of the 17 interview participants were White British, half of the FG participants were White British while four were from other European countries. Compared to the interview participants, the majority of whom lived in the 50% least deprived areas in England, the FGs had a more even distribution ranging from the most deprived to least deprived areas. One participant lived in Southampton, but declined to provide her complete postcode so her IMD could not be assessed.

Table 5.2 *Demographic characteristics of interview and focus group participants*

Description	All participants (n=27)	One-to-one interviews (n=17)	Focus groups (n=10)
Age at interview (y)			
21-25	2	1	1
26-30	9	4	5
31-35	7	5	2
36-40	9	7	2
Home index of deprivation quintile[a]			
1	2	1	1
2	6	3	3
3	5	4	1
4	5	3	3
5	7	6	1
Number of children			
1	18	8	10[c]
2	8	8	0
3	1	1	0
Highest level of education			
A-level	4	4	0
HND[b] or equivalent	2	1	1
Degree or above	21	12	9
Ethnicity			
White British	21	16	5
White other	4	0	4
East Asian	1	1	0
Black British	1	0	1

a Home index of multiple deprivation where 1=most deprived
b Higher national diploma
c Current pregnancy is counted as a child for consistency

5.4.2 Themes identified from the data

Thematic analysis of the interview data yielded a total of six themes with three or four sub-themes each. A) What behaviours are important during pregnancy? B) What keeps me from improving my health? C) What things in my life help me to be healthy? D) How did I use pregnancy-specific resources? E) How did I engage with the research nurses' support? F) Why do I want to be healthy? A description of the themes and sub-themes included in the final coding frame is shown in **Table 5.3.**

Table 5.3 *Final coding frame resulting from thematic analysis*

	Themes	Descriptors
A.	**What behaviours are important during pregnancy?**	Health behaviours that women viewed as important, or talked about changing during pregnancy
	A1. Diet	Diet is (not) important
	A2. Physical activity	Physical activity is (not) important
	A3. Smoking and alcohol	Avoiding smoking and/or alcohol
	A4. Other concerns	Any other lifestyle factors identified as important
B.	**What keeps me from improving my health?**	Barriers to improving health or reaching goals
	B1. The way pregnancy makes me feel	Pregnancy-specific experiences
	B2. My health is not a priority	Lack of interest in improving own health
C.	**What things in my life help me to be healthy?**	Facilitators to improving health or reaching goals
	C1. I have to be healthier because of my pregnancy.	Cravings or health conditions make women want to eat a healthier diet
	C2. I have always had a healthy lifestyle	Being healthy comes naturally
	C3. People around me are healthy too	Social support for maintaining/improving health
	C4. My environment encourages healthy behaviours	Environmental factors such as food availability
D.	**How did I use pregnancy-specific resources?**	Sources of support and advice that women found helpful (or not)
	D1. Baby's development	Reading about how the baby is developing
	D2. Specific concerns	Looking up specific symptoms or guidelines
	D3. To help me improve my health	Advice or information related to improving diet or increasing PA
E.	**How did I engage with the research nurses' support?***	Experiences and engagement with the HCS intervention
	E1. I realised that they were trying to support me to set and reach health behaviour goals	Participants describe the HCS skills used
	E2. The support I had helped me to be healthier (or not)	How the nurses' support effected behaviour change, or not
	E3. I set goals and tried to meet them (or not)	Engagement with goal-setting and effort made to reach those goals
F.	**Why do I want to be healthy?**	Motivators for eating well or exercising
	F1. I want to do the best I can for my children	Motivated by concern for children's health
	F2. I want to stay healthy or get healthier	Motivated by concern for own health
	F3. I don't want to be fat	Motivations related to gaining excessive weight or retaining weight post-pregnancy

*Only relevant to one-to-one interviews

The themes identified from the analysis are now summarised below with quotes drawn from the interview and FG transcripts to illustrate them. Each interview quote is followed by the woman's age, number of children and home IMD (on a scale of 1-5 where 1=20% most deprived in England) to show the spread of the data and to provide context. FG quotes are followed by FG1 or FG2 to show which FG the quote was taken from. Where more than one person is speaking, '**I**' indicates 'interviewer' and '**P**' indicates 'participant.'

5.4.2.1 Theme A: What behaviours are important during pregnancy?

When discussing a healthy pregnancy, all interview and FG participants acknowledged both diet and physical activity as relevant factors. All agreed that diet was important to some extent,

although the degree to which they believed it affected their health or the health of their babies varied widely. While some women knew that what they ate would affect the baby, others suggested that their diet probably made little difference even if they accepted that it was something to be aware of.

> *It's just, everything that I consume, there is always thoughts about, will it affect its eyes? Will it do this? Will it do that? So, it's all down to that. (FG2)*

> *I don't know 100% how much difference it makes to the development of the baby if you ate McDonald's every day… I don't think there's that much of a link between the two things from my understanding. (30; 1 child; IMD 4)*

Physical activity was also a popular topic of conversation, and almost all women agreed that physical activity was important during pregnancy. However, as with diet, there was considerable variation in the extent to which they felt this way, and in how much exercise they reported undertaking.

> *If you are already at that level it's okay to carry on. But if, say me, quite lazy and sedate, best not to suddenly think, 'oh… I'll run a marathon.' Which is handy, so I didn't feel any pressure to do a great amount of exercise. But a bit of yoga, which is basically bouncing on the ball and stretching your arms… (30; 1 child; IMD 4)*

> ***P**: It's changed. So like, I was doing spin up until so many weeks and then it was just hurting my back so then I took on swimming instead. So, the type of exercise has changed.*
> ***I**: Do you think you're still doing the same amount?*
> ***P**: I'm probably doing more because I feel more motivated. (FG1)*

Aside from diet quality and level of physical activity, there were some other factors that women identified as defining a healthy pregnancy. Closely related to diet quality was the avoidance of certain foods such as pâté and soft cheeses. This was discussed by six of the 17 interview participants, with some reporting actively avoiding such foods while others believed that they were not likely to cause harm. These disparate views are summarised well with quotes from two women with differing approaches to pregnancy. One woman was relaxed towards most aspects of pregnancy and said:

> *It's probably not going to be the worst thing in the world if I do eat soft cheese or whatever. (40; 2 children; IMD 3)*

The other woman was keen to follow all of the NHS guidelines to the letter and said:

I had a mouthful of brie by accident. Not by accident, obviously I knew I was eating it – you know when you just totally forget? I felt guilty for about two weeks. (30; 1 child; IMD 4)

Another frequently-mentioned factor was alcohol, with around half the interview participants touching on the subject. Three participants mentioned giving up alcohol as a passing comment, while two women specifically stated that they found it difficult to stop drinking altogether. Giving up alcohol was briefly mentioned in FG1, but was not discussed in detail. The other women who mentioned alcohol reported cutting down, believing that an occasional drink was not a cause for concern. Less frequently discussed topics were mental health, sleep, smoking, caffeine, and the desire to go through pregnancy without complications.

5.4.2.2 Theme B: What makes it difficult to be healthy?

For most women, pregnancy introduced a number of barriers to eating a balanced diet. While they believed that diet was important, participants often said that they chose foods that would help them manage morning sickness, and some talked about particular cravings. Starchy foods were often favoured in the first few months of pregnancy as they helped women cope with nausea.

I hit six weeks and I just felt like absolute rubbish, and I pretty much lived on rice cakes and mashed potato for ages. It was just anything to settle my stomach, and that's all I fancied. So at work, throughout the day, I was just nibbling on rice cakes all day. (29; 1 child; IMD 3)

I get hyperemesis and I vomit and vomit until about six months. Both times, until almost six months. And so, I didn't really eat anything except crisps and bread and Coke […] really starchy things to keep it down. (40; 2 children; IMD 3)

Many women found it difficult to remain physically active as they progressed through pregnancy, with tiredness being the main barrier. Some also said that their usual mode of physical activity was not suitable for pregnancy, and they found it difficult to change their routines and incorporate different activities.

As I got more pregnant, it got harder. And he's a very strong dog. He pulls a lot as well, so I got to the point where I was like, 'I'm just not doing this anymore.' (28; 2 children; IMD 5)

Things just kept on getting in the way and I mean I could have gone swimming 8 'til 10 every night, but by the time it got that late I was just so tired. So I think if I could have gone earlier then I think it would have made a bit of a difference. But it might not 'cause if you're still tired anyway and there's constantly so many things… I found it really difficult to find new habits with exercise whilst I was pregnant. (36; 2 children; IMD 3)

> *Well before I was pregnant I was cycling to work. But then I found that I've had to sort of really change exercise-wise because I couldn't fit it in with my normal routine. I'd have to do something extra on top, which was a difference. (FG1)*

Fewer pregnancy-related barriers were discussed with regard to physical activity than diet. Rather, the post-natal period tended to influence physical activity levels more than pregnancy did. Many interview participants said that they needed to recover from childbirth before they could return to doing any physical activity.

> *I had some problems with my episiotomy and the stitches came out. That was quite painful and sore, so I actually found walking quite difficult… For the first two months I really couldn't walk very far at all*. (36; 1 child; IMD 2)

> *It was difficult for the first few weeks because obviously you can't, I couldn't continue my swimming. I couldn't do any of that side of stuff because obviously you can't until you've had your six-week check, so from that point of view you almost lose the momentum. (31; 3 children; IMD 2)*

Even when women wanted to exercise, they found that it was difficult to find things they could do with a new baby, and that were appropriate for their physical needs.

> *I know there's one on the other side of Southampton… but [baby] doesn't like the car so it's not very good for us to travel. If there were more classes where you could take the babies, I'd be keen to do that. Also, that are a bit actually designed for post-birth, because the one that I've been to on the common was fine, but there's a lot of jumping up and down and I don't think that's really designed for, you know, your pelvic floor after birth. (31; 1 child; IMD 2)*

For those who had had more than one pregnancy, already having a child presented additional barriers such as lack of time or energy. This was true both during pregnancy and after giving birth.

> *The second time you just sort of have to continue as you are because you've got someone else to think about. So actually, I didn't make nearly as many changes to my life as I did the first time I was pregnant, when it was just me and my partner… I had the luxury of being able to focus more on the first baby, whereas the second one I didn't. (40; 2 children; IMD 3)*

> *We haven't been on as many walks as I used to do with [my first child] when she was little. We used to go for a walk after my husband got home from work […] Course we can't do that now when we've got a toddler as well. (37; 2 children; IMD 3)*

Pregnancy-related barriers to improving diet and increasing physical activity were reported by most participants, regardless of their apparent intention or desire to change these behaviours. However, one factor that was not necessarily related to pregnancy was some women's apparent lack of interest in their own health. A few women in this sample reported having other priorities in their lives, and had little desire to try to improve their diet quality or be more active.

> *I'm sure there's plenty of other women out there that are a lot more together than me, and probably are out and, you know, jogging around the block at 7 o'clock in the morning or whatever. And you know, that's just not me. I'm not together. (40; 2 children; IMD 3)*

5.4.2.3 Theme C: What things in my life help me to be healthy?

While pregnancy usually introduced barriers to improving or maintaining their health behaviours, a few women found that they craved healthier foods in pregnancy, which made it easier to eat a balanced diet.

> *I think the first trimester when I felt a bit queasy, the fruit and veg was like, that would go down well. And then I think that's kind of the habit I got into, and kind of stayed in throughout the pregnancy. (36; 2 children; IMD 3)*

> *I have found that actually, what I've craved, since being pregnant I've eaten far more fruit than I ever would eat because I just have to have it, which is really convenient. And equally having, you know I really don't like milk, but since being pregnant I've wanted to have cereal every single day. (FG2)*

There were two FG participants (one in each group) who had developed GDM and were therefore compelled to avoid sugar and this was the main factor influencing their diets.

> *Recently I've had to change to low-sugar, low-carb because I've been diagnosed with gestational diabetes. (FG1)*

> *I think that the diet there is… it's all about controlling your blood sugar… After they diagnosed me with this diabetes, the diet is so strict I actually lost like six kilos. (FG2)*

However, these responses were uncommon and the factors supporting women to be healthier were usually not specific to pregnancy. Firstly, some participants seemed to find it easier than others to maintain a healthy lifestyle or to strive to reach their health behaviour goals during their pregnancies. For a few women, staying healthy appeared to come naturally.

> *I know how to eat healthily – I've always done it. (30; 1 child; IMD 4)*

> *Oh, just that I have always been like, I really enjoy exercise. And then, you know… I didn't want to not do anything and sort of stagnate when I was pregnant. I wanted to keep up doing something. So, I think that was part of it too; the fact that I'm just naturally an active person. (35; 1 child; IMD 4)*

For those who said they were healthy people, this focus on health often extended to their households or social circles and the social support further enabled them to maintain healthy lifestyles during and post-pregnancy.

> *I'm not panicking about any of it. As I said before, obviously with someone in the house who likes to cook, and he cycles a lot, so he wants to stay fit and healthy and the boys are always active so it's quite easy. It's not a household where everyone wants to eat, you know, junk food. (31; 3 children; IMD 2)*

> *My neighbour next door's got a baby as well, so we're quite close. We're going to start… she goes walking as well because she's got a dog. You know the Couch to 5k?[…]I did that with her. That's how I started running, and I eventually ran two 10k races after I had [my first child]… so we're going to start that in a couple of weeks. (28; 2 children; IMD 5)*

In addition to their social networks, some women identified other factors in their environments that made it easier to maintain a healthy lifestyle. These included easy access to healthy food at home or work, and having responsibilities that kept them active.

> *I was very lucky 'cause where I work we have our lunches included… So it was really easy for me to eat quite healthily. I always had melon for my dessert instead of having the… oh, I would allow myself the odd crumble here and there […] but the majority of the time, I would have sort of melon or strawberries or something like that. But yeah, I ate a lot of salads and stuff throughout the pregnancy. (31; 3 children; IMD 2)*

> *I was really active because of [my son] and I didn't want [the pregnancy] to affect him at all. Having a dog really helped because it meant that I would always go out and walk the dog. (35; 2 children; IMD 5)*

Those who were able to identify factors that helped them to stay healthy usually talked about long-term circumstances, which were not necessarily related to being pregnant. While there are a number of pregnancy-focused resources available to support women to maintain a healthy lifestyle, most participants did not describe these resources as being particularly important to them.

5.4.2.4 Theme D: How did I use pregnancy-specific resources?

Nearly all of the women interviewed identified at least one resource used to seek advice or information in pregnancy including books, mobile apps, classes, internet searches and social support groups. However, most of these resources were used for information about the development of the baby, or to look into a specific concern. Updates about the size of the baby were particularly popular.

> *I get an alert every week that tells me, 'okay, you're at this stage. You're this many weeks, and this is what it looks like. This is the foot size, etc.' So I read every single week exactly what is happening in the development and then I'll look at the tips and go from there. (FG2)*

> *I always remember the BabyCentre ones because it was like, 'this week your baby is the size of a tomato' and that really grabbed me because I was like, I'd text my friends going, 'banana.' You know like tell them what size. (35; 2 children; IMD 5)*

The other common reason for accessing pregnancy-related resources was to look up a specific concern. For example, if women were experiencing a new symptom, or if they wanted to know about certain guidelines, they would search the internet or speak to their midwives.

> *I didn't use anything like as an ongoing thing, but if I had a query, you know, like 'oh my hands have swollen,' or whatever. Yeah, like Babycentre.com or something. (40; 2 children; IMD 3)*

> *I did look at the NHS website, for the list of foods that you can't eat especially. Because quite often you'd be at a restaurant or something and you think, 'oh am I allowed to eat this cheese' or whatever it is. So, I found that quite helpful. (31; 1 child; IMD 2)*

FG participants, who were currently pregnant, and were pregnant for the first time, talked more about worries they had about the baby and the pregnancy, while such concerns were rarely mentioned in interviews with SPRING participants.

> ***P**: I spoke to the day unit yesterday because I hadn't felt the baby move all morning. And they were very reassuring and helpful.*
> ***P**: Yeah, I had the same, but they just told me to come and they put the electrodes and they were measuring. But they said it's because it was so hot, the baby just got tired.*
> ***P**: Mine was I didn't feel it for the entire day and I got really worried. But they said to me, my placenta's right here at the front. They said he was kicking into the placenta, but I couldn't feel it. (FG2)*

The social features of some resources, such as Facebook groups and online forums, were primarily used for sharing pregnancy experiences as women found this to be reassuring. Most women did not use forums for advice, but clearly preferred trusted sources of information including NHS Choices or speaking to a midwife.

> *Sometimes [the forum] was useful because people kind of say, 'oh were you having this?' and you think 'oh yeah, that's what I'm feeling like at the moment.' If they're saying that they're having a similar experience, then it can make you feel a bit better that you know that you're not the only one. (31; 1 child; IMD 2)*

> *I'm part of a Facebook group for September babies…. It's good to have access to people that are kind of going through the same experiences, or some of them have had children before so they can refer back to their experiences as well and advise when to go to hospital if you're not too sure. So that's helpful. (FG1)*

> *You just know your sources, don't you? So if it's, say, Baby Centre, not the forum bit, but the actual information, I trust. What to Expect, I trust. Bounty, I trust… The forums you don't necessarily trust as gospel, but interesting to get. (30; 1 child; IMD 4)*

> ***P**: I always try and avoid Google unless it is a trusted site, just because when you read things, it's worst case scenario and it just makes you more scared.*
> ***P**: Yeah, I think forums as well.*
> ***P**: Oh, they're bad!*
> ***P**: Like certain websites are fine, but forums are just other people and sometimes you can just get a whole bunch of other stuff. It's just different people's experiences.*
> ***P**: Unfortunately, they seem to pop up often before the NHS website, so you have to scroll down and ignore them. (FG2)*

For diet support, most of the interview and FG participants identified a resource they had accessed and usually these were related to food restrictions rather than diet quality. A few women, though, did use the internet to determine which foods they *should* eat. Similarly, about half of participants identified a resource they used to help them be physically active, such as attending antenatal exercise classes or using a local swimming pool. There was considerable overlap between the women who identified a source of dietary support and those who accessed support for physical activity, and many women did not specifically identify any resources for diet or physical activity support in pregnancy. In discussing pregnancy apps, one of the women did not feel that lifestyle support was an interesting feature, saying that it was:

More interesting to see my baby's the size of a honeydew melon this week rather than like, 'you should be eating that honeydew melon.' I guess I like to think I kind of know what it is to eat healthy. (35; 2 children; IMD 5)

Only a few women sought information or support for a healthy diet, but one woman wanted to be sure she had the best diet she could have during pregnancy and said:

I did print a list of every food you're supposed to eat, every vitamin you're supposed to eat in pregnancy. So I tried to eat different things off that, but I found it really hard because there's so many different things that you're supposed to eat and there's lots of pulses and lentils and things like that. (31; 2 children; IMD 5)

Accessing diet and physical activity support changed slightly after women gave birth. More than half of the SPRING women interviewed said that they were using at least one resource to lose weight or get fitter after pregnancy. Post-pregnancy resources identified were weight loss groups, exercise classes, an exercise app and use of an activity tracker.

5.4.2.5 Theme E: How did I engage with the research nurses' support?

SPRING participants were blinded to the HCS intervention, and were generally unaware that the extra support was a component of the trial. Despite this, they were all able to talk about the way the research nurses asked them about their health and encouraged them to set goals. In general, women were very positive in discussing this support. Nearly all reported setting a physical activity goal and more than half of those also set a diet goal. One woman said that an additional goal was not to drink any alcohol and one wanted to abstain from smoking. Quotes to demonstrate women's experience of this support and the goals they set are below:

I think actually the nurses were brilliant 'cause they were never like, 'well, you should be doing this…' they weren't telling me what to do. They were kind of asking me what I would like to do and getting me to think about what I want… it got me thinking and a bit more focused on what I should be eating and doing. (36; 2 children; IMD 3)

She sort of said right at the beginning of the interview, 'what goals, what goals were you setting?' So my goal was to swim right up until I was ready to drop. And then every time I spoke to her she would then follow up with more questions with regard to, you know, 'okay so are you still swimming? Are you still… is that still a goal? Has your goal changed?' So that was really helpful. (31; 3 children; IMD 2)

There were two SPRING participants who did not set any goals. One of these women felt that the research nurse did not think she needed to make any changes, saying:

> *I didn't really set any goals with them actually. We did talk about doing swimming… but when she took my measurements she wasn't overly concerned that I was putting on excess weight. So, for her I think she said, 'whatever you are doing is working, so just continue to do that.' (38; 2 children; IMD 5)*

The other woman who did not set any goals had a more negative attitude towards her experience and repeatedly stated that she was lazy and not goal-oriented:

> *I don't… I'm quite a lazy person, so I think I don't generally set myself many goals. I am actually just quite lazy. (40; 2 children; IMD 3)*

> *I just like to get through things and see what happens and kind of assess it at the end. I'm just not a very goal-orientated person. (40; 2 children; IMD 3)*

Among the women who did set health goals, there was a range of opinions about their helpfulness in supporting improved diet or increased physical activity. Some women believed that they would have been just as healthy without the extra nurse support, although none of these women had negative feelings about the intervention. Most women felt that having healthy conversations with the research nurses did encourage them to be healthier, saying that it was either because they knew they were going to be held accountable, or that the conversations encouraged them to reflect on their behaviours and made them more aware of the importance of their health. In addition to supporting women to set goals and improve their diets or increase physical activity levels, many SPRING participants appreciated that the research nurses were interested in their health rather than only the health of the developing baby. Interview quotes to demonstrate the range of participant experiences are shown below:

> *I think it was a good thing because sometimes you do need a little bit of a kick to kind of do things that you actually do want to do anyways. (39; 1 child; IMD 4)*

> *It does make you keep up everything you set because you almost feel when you've got someone ringing you in a few months' time, you want to be able to say to them, 'yes, yes! I've still done it.' (31; 3 children; IMD 2)*

> *I found that perhaps I felt a bit guilty that I hadn't achieved them, and that I had to make up an excuse why. I did feel that maybe… because I wasn't fulfilling them I was somehow letting myself and my future child down by not achieving those aims. (36; 1 child; IMD 2)*

> *It was quite nice to have that, that time to actually really think about <u>me</u> pregnant and not just the baby whilst I was pregnant, if that makes sense. (36; 2 children; IMD 3)*

Levels of engagement varied as some women had set clear goals towards which they were still working, but others had not set specific goals or could not remember them after their participation in SPRING had ended.

> *I said to her that I was going to go back to Slimming World, which I have done. She asked me if I was gonna… because after [my first child] was born, I started smoking within two or three weeks of her being born …She knew that and she asked if I was still smoke-free. I said yeah. And basically, that was the major goals. (23; 2 children; IMD 1)*

> *I don't… I don't know that I did, really. I found that quite hard. Yeah, they kept asking about things like that. I didn't really set any goals. (40; 2 children; IMD 3)*

> ***I**: Do you remember what specifically you said about exercise?*
> ***P**: I said yoga… Aqua-natal… Or did I say swimming instead 'cause I was already doing it? I said yoga and swimming I think.*
> ***I**: Do you think that talking about that with the nurses had any […] influence on your motivation to exercise, or to make sure you went and did it?*
> ***P**: Um… don't think so. I mean they were lovely. Really lovely, really supportive, but I kind of knew I wanted to do that anyway. (27; 1 child; IMD 5)*

SPRING participants' varying levels of engagement with the research nurses' support was related to their motivation to improve or maintain their health during pregnancy. Most women engaged with the support because there was something they wanted to improve, but some women showed a lack of engagement. This lack of engagement appeared to be either because women did not think their health behaviours were a priority, or because they felt that they could be as healthy as they wanted without any additional support.

5.4.2.6 Theme F: Why do I want to be healthy?

Of the factors that women identified as motivating them to eat well or be physically active, the most common were: the desire to do the best they could for their children; concern for their own health; and the desire to lose weight after pregnancy or not gain excessive weight during pregnancy. There was an apparent difference in priorities between the one-to-one interview participants who had taken part in SPRING and the FG participants who had not. Most SPRING participants said that they were primarily motivated by their own health and body weight while FG participants mostly reported being motivated by the baby. In the one-to-one interviews, women talked about their own health and how it was affected by their pregnancies. This was often related to weight gain and retention, but also referred to their health in general.

I think to be honest it was probably for me rather than for the baby because all the advice I had was… the baby will take what they need and your body will prioritise the development of your baby. It's just you that suffers if you hadn't eaten properly, and I wanted to be healthy after I'd given birth. (31; 1 child; IMD 2)

I just don't want to be this fat mum waddling up to the school gates every day to pick up their children, you know?... But also, I'm worried about keeling over and having a heart attack because there's been problems in my family – heart problems… I'm overweight and I don't really look after myself and I've got two children. Something like that could happen to me, and I want to be healthy. (28; 2 children; IMD 5)

I realise having children I'm never going to have the figure or the tummy that I had when I was in my twenties, and I don't really care so much about that, but I don't want to be like a fat mum… I mean, I don't want to be a fattist, but it doesn't appeal to me at all getting fat… I sometimes think when you're pregnant you can kind of not be aware. (35; 2 children; IMD 5)

Among SPRING participants, the baby's development was occasionally discussed as a motivator for maintaining a healthy lifestyle in pregnancy:

I do think that eating healthy is more important because that's what they get, isn't it, from you. (23; 2 children; IMD 1)

In contrast to the one-to-one interview participants from SPRING, FG participants said very little about their own health. In FG1, participants showed little interest in discussing their own health or weight gain, saying that they did not see much cause for concern and any concerns they did have were related to giving birth. Exemplar quotes from FG1 are shown below.

I'm not really that stressed about anything, so I just think I will just go slow and I will see… I haven't put on too much weight or that kind of thing, so I don't see why if I've been all good before, I wouldn't be after. So yeah no, I'm not really worried about that. (FG1)

I was concerned, but like literally all the weight I've put on is in my belly and my boobs, so I'm not too concerned now. And I'm still rather slim – I've only put on the weight from the baby. I think, well hopefully I'll go back to slim. (FG1)

I think I just have in my head that you have a… I don't know if there's any factual basis… but that labour might be a bit easier if you're physically fit. (FG1)

In FG2, participants discussed their diets and physical activity in more detail, and agreed that the baby was their primary motivator.

> ***I**: So how much of that is motivated by wanting to do the best for the baby, and how much of it is about your own health, not wanting to gain too much weight for yourself?*
> ***P**: I'd say 50/50*
> ***P**: I'd say for me, it's more about the baby. I've never really done it for myself, being perfectly honest.*
> ***P**: Yeah, I would agree.*
> ***P**: For me, it's all for the baby.*
> ***P**: Yeah, I think if it wasn't for the baby, this diet for diabetes, I wouldn't be able to stick to it… as I said to many people, if it wasn't for a baby, I wouldn't stick to that. No way! (FG2)*

One participant in this group was worried about her body weight, but this was still motivated by concern for the baby's health and by her desire to be able to have a home birth.

> ***P**: I'm trying to be far more healthy because my BMI is horrendous, absolutely horrendous. So definitely, I'm really really trying not to put on any weight in pregnancy…I'd definitely say I'm far more conscious of it knowing that baby's going to have what I'm putting in. I've hardly, well I haven't really put on any weight.*
> ***I**: So, have you had advice from a doctor or midwife saying 'try not to put on any extra weight?'*
> ***P**: Yeah, definitely. 'Cause I'm trying to have a home birth as well. So that's sort of one of the things. I agreed not to put on too much weight, and I haven't so far, so I'm happy. (FG2)*

5.4.3 Emergent theme: Health Identity

A concept that was not explicitly discussed in the interviews or FGs, but which emerged particularly from the one-to-one interview data, was linked to women's personal identity and its relation to their health. That is, those who said they had always been healthy, or the kind of person to stay active, generally reported maintaining healthier lifestyles than those who did not identify as being particularly healthy. This can be seen in Themes B and C. This identity as a healthy person (or not) also influenced SPRING participants' engagement with HCS support and the idea of making a change. Women who did not consider themselves to be particularly healthy, or view their health as a priority, were less likely to *want* to change their behaviours and had not really engaged with the goal-setting element of the HCS intervention. This lack of engagement can be seen in the quotes presented as part of Theme E, and in additional quotes presented below.

> *I'm just not that sort of person… My goal was to just get through the pregnancy relatively well, so I didn't want to set myself a goal of saying 'I'm going to do yoga twice a week' or whatever. Or 'I'm not going to eat any chocolate or anything.' I just kind of wanted to get through it. (40; 2 children; IMD 3)*

> ***I**: What goals did you set with the nurses?*
> ***P**: I can't remember. I think it was perhaps to try and have half an hour of exercise a day… and I think I wanted to eat more fruit. (38; 2 children; IMD 5)*

At the other extreme, women who viewed their health as a priority, and who viewed themselves as very healthy people, were unlikely to feel that they *needed* to set goals or change their behaviours and had relatively little to say about their goals.

> *I wouldn't necessarily say those goals were really important to me, but the general being fairly healthy … it wasn't so much about the goals, it was just the [trial] that got me thinking generally about what you're eating, what you're putting in your body. (35; 2 children; IMD 5)*

Those who fell between these two extremes were more likely to show interest in improving their health behaviours and to engage with available support. These women often had more to say about their goals in the interview, and had tried to change their health behaviours.

> *I said I'd try and get out at least four times a week. That was when I stopped walking the dog. I was quite pregnant by that point and it was heavy going. (28; 2 children; IMD 5)*

The extent to which women view themselves as healthy people can be conceptualised as their 'health identity,' where women range from 'health-disengaged,' to 'health-focused.' **Figure 5.3** is a visual representation of this concept and its relation to women's openness to change. The statements that fall on different points in the figure are not quotes from the interviews, but are informed by the data and intended to summarise women's varying attitudes.

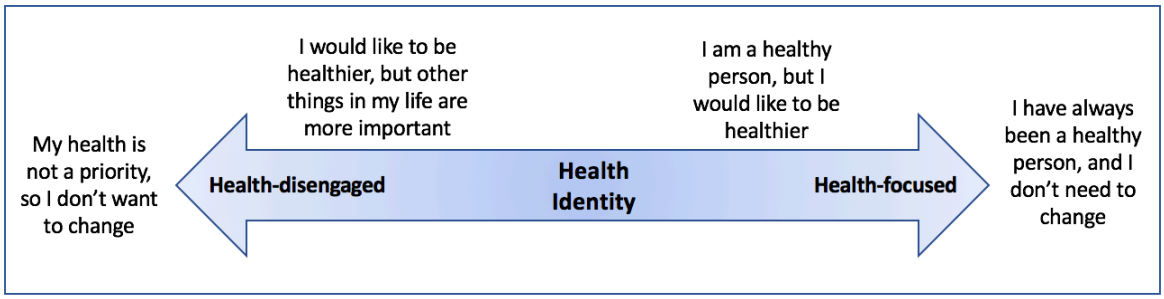


Figure 5.3 *The proposed spectrum of health identity extends from 'health-disengaged' to 'health-focused'*

Pregnancy and motherhood influenced women's attitudes towards their health behaviours, and this also appeared to be related to their health identities. Interviews with participants who appeared not to prioritise their health (health-disengaged) focused much less on their health in pregnancy because they were not interested in discussing this topic. There were two participants who were especially disengaged with the lifestyle side of the interviews, and preferred to talk about the other elements of their experience in SPRING, their pregnancies, and the other concerns they had in their lives. Both of these women also talked about prioritising their children and not their own health.

> ***I**: How much do you think about trying to get your five a day in? How important is that to you?*
> ***P**: Not really that much to be honest… I think I focus more on trying to get my daughter to eat it. (38; 2 children; IMD 5)*
>
> *Looking after the baby is always still my priority rather than looking after myself at that stage. (40; 2 children; IMD 3)*

Interviews with these two participants suggest that, for those who are very health-disengaged, pregnancy may not provide sufficient motivation to encourage a positive change in diet or physical activity and these women may not engage with the kind of support that is provided through HCS.

For some participants who were otherwise quite health-disengaged, diet and physical activity were not generally a major focus or priority, but pregnancy and motherhood provided extra motivation to engage in healthier behaviours for the sake of their children (as shown in Theme F). One interview participant appeared to be exclusively motivated by concern for her children, and did not mention her own health as being important at all. That is, a change in her identity to mother and role-model supported positive changes to her lifestyle. In talking about joining Slimming World and giving up smoking, she said:

> *I don't want to teach my children that they've got to be skinny because they don't have to be skinny. They just have to be healthy, and that's what I want. So, I can't teach them not to smoke if I'm smoking. I can't teach them not to drink if I'm an alcoholic. I can't teach them to be healthy if I'm not healthy myself. (23; 2 children; IMD 1)*

While the concept of health identity was not informed to a significant degree by the FGs due to the fact that FG participants had not been exposed to a behaviour change intervention, a pregnancy-related shift in attitude towards health behaviours was seen in all of the participants in FG2. As shown through Theme F**,** these women were primarily motivated by the health of their babies. One woman explained that worry over potential harm to the baby was the main factor that made her more aware of her diet.

> *If you do something, and you have a baby, and the result is that something was wrong or something happened because you could have done something differently, I think that would weigh on your conscience very heavily. And you would feel like, 'I could've been unselfish, and I could have done this or that.' So that's why, for me, it's 100% about the baby. Otherwise I'm not really bothered. (FG2)*

Another woman in FG2 stated that she was otherwise quite lazy, but had started exercising when she fell pregnant.

> *I exercise more… I was super lazy otherwise, but I started when I found out I was pregnant… I think I wasn't really concerned with exercising before. I'm quite lazy. (FG2)*

Interestingly, one of the SPRING participants also described herself as lazy and this was her reason for *not* engaging with HCS or trying to improve her health behaviours during pregnancy (see **Section 5.4.2.5**). Clearly, pregnancy was an impetus to change for one health-disengaged woman, but not for the other. One difference between these two women was that the FG participant who was motivated to change was in her first pregnancy, while the interview participant who was not motivated had two children.

Most of the interview participants were somewhat health-focused, and open to change to improve their health. These were participants who, to some extent, identified as healthy people, believed they had generally healthy lifestyles, and viewed diet and physical activity as being important. One characteristic that seems to distinguish these participants from the relatively more health-disengaged is that they were not solely motivated by pregnancy or baby-related factors, but rather they were also interested in maintaining or improving their own health. Concern about not gaining too much weight, or losing weight after giving birth, was often cited as a reason to remain active during pregnancy, and this appeared to be linked to participants' identity, saying that they did not want to become a fat person or an unhealthy person.

> *I think some people can slip into, 'oh, I'm fat now.' Then if you have another pregnancy… you know, I was quite scared about keeping my weight then having another baby and then just magnituding [sic]. So, I kind of wanted to lose my baby weight. I've seen a lot of people do that; they kind of put on four stone and they were healthy people, you know? (35; 2 children; IMD 5)*

Those who were the most health-focused said that they had always been healthy, and did not require additional support to improve their diet or physical activity behaviours, or to maintain healthy behaviours during pregnancy.

5.5 Discussion

5.5.1 Factors associated with diet and physical activity in pregnancy

Interviews with 17 recently pregnant women and focus groups with 10 pregnant women have identified a number of pregnancy-specific factors that influence diet and physical activity. Firstly, it is clear that pregnancy and the post-natal period introduce physiological barriers such as nausea, pain and fatigue, which make it more difficult to eat a balanced diet or be physically active. While pregnancy is sometimes viewed as a 'teachable moment' where women are inclined to improve their health behaviours,[114,297] it is important to acknowledge that it is also a time when it can feel particularly difficult to change. Quantitative research supports this finding as an analysis of data from 2270 Southampton Women's Survey (SWS) participants showed that 89% experienced nausea in pregnancy and more severe nausea was associated with changes in diet quality. Common changes included a reduction in a number of healthy foods including vegetables and an increase in white bread and soft drinks.[162] Given this, supportive interventions may be more effective if they help women to focus on changes they *can* make rather than changes that would be ideal. For example, if a woman is suffering with severe nausea, it may not be possible for her to increase her vegetable consumption, but she could perhaps replace some of the white flour products she is eating with whole grain alternatives. Encouraging women to reflect on their individual circumstances and come up with their own ideas about what they can change, as is done through HCS, could be an important intervention component.

Another factor that influenced women's health behaviours and experience of pregnancy was whether or not they already had a child. Women in their first pregnancy were generally more motivated to be healthy and more concerned about following strict guidelines. While concern about the health of the baby was relevant to many participants, this was of particular importance to women in their first pregnancy. It has been suggested that while pregnancy introduces changes to all women's lives, women in their first pregnancy are experiencing a change to their personal and social roles for the first time, making them particularly amenable to improve their health behaviours.[114] Furthermore, women in their second pregnancy reflected that they had less time and energy to focus on their health than they had in their first pregnancy, making it more difficult and less of a priority to improve their health behaviours. This suggests that a woman's first pregnancy may present a unique and particularly valuable opportunity for change. On the other hand, women who are not in their first pregnancy may require more support and motivation than nulliparous women to achieve a similar level of behaviour change.

While becoming pregnant encouraged women to improve their health behaviours for the benefit of their babies, many interview participants also expressed concern over their own health and weight. Indeed, many interview participants stated that their own health or weight was their main motivation to be healthy. In contrast, the FG participants did not appear to share this view, saying that they were primarily (and sometimes exclusively) motivated by the desire to do the best they could for their baby. This difference in priorities between study populations may have resulted from the fact that the interview participants had already given birth, and were therefore more focused on losing weight and getting fitter at the time of the interview, while the FGs were conducted with women who were currently pregnant, and were therefore more focused on their babies. It is likely, though, that this difference resulted at least in part from the fact that interview participants had all received HCS support and been encouraged to think about their own health and health behaviours throughout their pregnancies while FG participants had not. As discussed in **Section 5.4.2.4**, the opportunity to focus on their own health was one of the things that SPRING participants appreciated about HCS support. If HCS supports women to prioritise their own health during pregnancy, this may provide additional motivation to eat well and exercise throughout pregnancy. Furthermore, women who are motivated only by their babies' health are likely to make only temporary changes for the duration of their pregnancies, as is seen with smoking,[85] while women who have begun to view their own health as important may be more likely to maintain the changes they make in the longer term.

Most of the factors that women identified as helping them to maintain a healthy lifestyle referred to their more permanent circumstances rather than circumstances that were unique to pregnancy, and social contacts were sometimes identified as valuable sources of support. Other studies have similarly concluded that social support is an important facilitator for physical activity in pregnancy,[298,299] suggesting that those whose household and social contacts do not encourage them to be healthy are at a disadvantage and may benefit from accessing alternative sources of social support. Potential sources of social support accessed by women in the current study included online forums, Facebook groups and antenatal exercise classes. Women who lack sufficient social support could be encouraged to access one or more of these resources, but health and social care practitioners should also be aware that many women will not seek any such support and these women may require more intensive intervention. Understanding of women's immediate environment and social relationships may help healthcare practitioners to identify and address individual needs, and to ascertain which patients may require more or less support for a healthy lifestyle in pregnancy.

Most women did not regularly use a website, app, book or other source of support for improving their diet or increasing physical activity. A number of participants reported looking at resources

such as babycentre.co.uk, which includes information and advice about diet and physical activity for each week of pregnancy, but users were primarily interested in the information about the baby's development rather than diet and physical activity advice. It is clear that enough information is readily available for pregnant women, and it is included in the resources they are already using. Therefore, further development of digital resources and provision of more information is not justified as a sole intervention. When women did access health or lifestyle information, they showed a clear preference for trusted sources such as speaking to a midwife or using the NHS website, suggesting that healthcare practitioners who are already having regular contact with pregnant women are ideally placed to encourage and support women to change. Part of this support could include signposting to existing reliable resources as required.

5.5.2 Health identity

Health identity was a key concept that emerged from the interview data. Some of the comments made by FG participants supported this idea, but conversation about engagement with behaviour change support was not possible with these groups as they had not been exposed to a particular intervention, and the nature of FGs made it difficult to explore concepts related to individual identity. Interview participants ranged from 'health-disengaged' to 'health-focused,' indicating the extent to which they viewed themselves as healthy people and the priority they placed on their health. Health-disengaged women did not view their health as a priority, were not motivated to change, and did not *want* to engage with available sources of support, including HCS. Health-focused women said they had always been healthy, viewed their own health as important, and did not feel that they *needed* to engage with available sources of support, including HCS. Women who were somewhere in the middle thought that their health was somewhat important, believed that there was some room for improvement and were more likely to engage with HCS support. **Figure 5.4** presents a (non-quantitative) conceptual schematic of the relationship between health identity and engagement with behaviour change support suggested by the data presented above. Furthermore, women with different health identities seemed to identify different motivators for wanting, or not wanting, to make a change and these motivators are included in the figure.

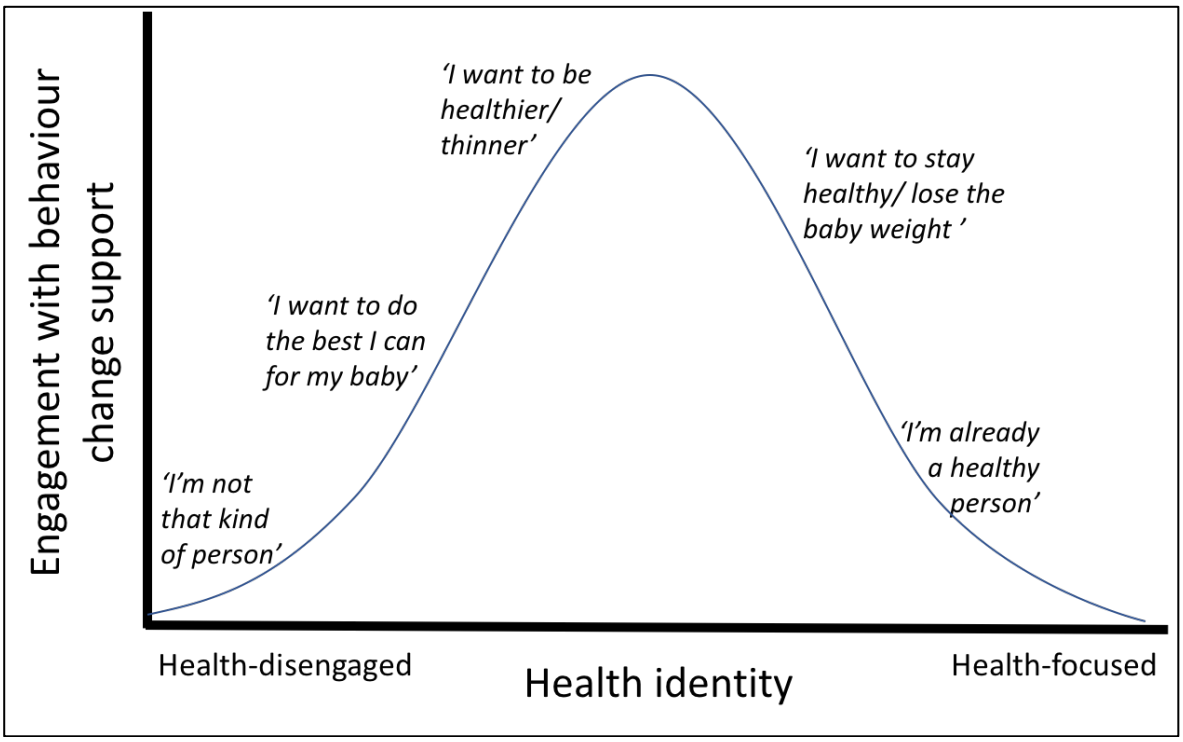


Figure 5.4 *The proposed relationship between health identity and engagement with behaviour change support is conceptualised as a curved graph. Primary motivators for change are described at different points on the graph.*

The relationship between health and identity has been studied previously.[300-305] Often, this work has focused on people with particular health conditions or disabilities and examined the effects of these conditions on a person's identity.[300] However, some research has focused on behaviour-related constructs including exercise identity[304] and healthy-eater identity.[303] These studies have shown that identity, in combination with self-efficacy, was an important determinant of health behaviours among university students. Specifically, a prospective study of healthy-eater identity[303] found that this construct (measured using a validated 9-item scale) was a significant predictor of fruit and vegetable intake. Self-efficacy in this study improved the fit of a regression model to account for 31% of the variance in fruit and vegetable intake, showing that healthy-eater identity and self-efficacy were both important in predicting intake of healthy foods.[303] Similarly, a few studies have shown that exercise identity was associated with exercise adherence.[304,305] This research lends support to the idea that a woman's health identity, in conjunction with other factors, may predict her diet quality or level of physical activity. It also suggests that health identity could be measurable as both exercise identity and healthy-eater identity have been measured. This would require the development of a specific tool which asked participants about the extent to which they view themselves as healthy and the priority they place on their own health.

While the concept of health identity has not been incorporated into any diet or physical activity interventions, and there is not yet any evidence to show whether it is modifiable, a recognisable

example of using identity to facilitate behaviour change is in smoking cessation strategies.[306,307] That is, a change in identity from 'smoker' to 'ex-smoker' or 'non-smoker' has been associated with successful quitting attempts.[308] A longitudinal study in the Netherlands found that, over time, smoker identity increased in smokers and decreased in ex-smokers.[309] It is possible that a similar principle could be applied to diet or physical activity change. If it is feasible to support a change in identity from 'I am not someone who jogs' to 'I am an active person,' or from health-disengaged to health-focused, such an intervention could lead to meaningful and sustained improvements in health behaviours.

5.5.2.1 Implications for intervention development and further research

The most health-disengaged women did not view their health or health behaviours as a priority, and pregnancy did not appear to change their attitudes. This lack of interest in health meant that they did not want to make a change, and therefore did not engage with HCS support. For health-disengaged women, goal-setting interventions may not be effective in engaging them in improving their health behaviours, suggesting that alternative strategies are required. For this group in particular, it is likely that individual-level interventions will not lead to a significant change in behaviour and wider environmental change is needed. Indeed, it is known that structural change is required to benefit the most disadvantaged in the population[310] and individual-level interventions that require agency are not likely to benefit those who are disinterested or unable to change. Therefore, policies are needed to make it easier for women to eat a healthy diet and be physically active without widening inequalities. In Southampton, for example, pregnant women are entitled to use public swimming pools for free. Such a scheme could be extended to support other behaviours, such as subsidising healthy foods for pregnant women.

Those who were somewhat health-disengaged generally did not prioritise their own health, but were often motivated by their pregnancies, and engaged with health advice for their babies' benefit. This appeared to be true even for those who had not had any exposure to a behaviour change intervention (FG participants). For somewhat health-disengaged women, pregnancy and the transition to motherhood provide a particularly valuable opportunity for healthcare practitioners to intervene and support improvements in health behaviours. However, changes that are motivated by pregnancy may only be temporary, as is often the case with smoking cessation.[85] Therefore, the task is two-fold when working with somewhat health-disengaged women: 1) There is potential to motivate women to improve their health behaviours by appealing to their desire to do the best they can for their baby and ensuring they are aware of the potential consequences of (not) changing their health behaviours; 2) Any improvements in health behaviours could be more permanent if they are viewed as a new normal and linked to the

woman's identity as a healthier person, rather than being solely linked to the baby's development.

Most of the interview participants fell on the health-focused side of the health identity spectrum. Those who were somewhat health-focused and motivated to maintain or improve their health behaviours often had a lot to say about their health goals and the strategies they used to meet their goals. For these participants, pregnancy was an opportunity to bring additional awareness to their own health and body composition, and the HCS support and goal-setting provided by the SPRING research nurses was acceptable and often supported women to strive for a healthier lifestyle. Again, when these women make changes during pregnancy, this should encourage a shift in health identity where the change becomes a permanent part of how they view themselves and their lifestyles.

Women who were very health-focused believed that they did not need to change their behaviours because they had always been healthy. For women who are very health-focused, pregnancy may not require a major change in lifestyle, so goal-setting interventions may not be necessary or cost-effective. However, having a baby introduced new barriers for some women, and while the most health-focused feel that they do not need to make a change during pregnancy, they may find it is more difficult to maintain their healthy lifestyle after giving birth. Therefore, it could be beneficial to encourage women to think about how they will overcome new barriers in the future and adjust to having a new baby or a growing family, and to any other changes that may arise after they give birth.

It is important to note that these conclusions are based on a relatively homogenous sample of women. Before developing new interventions, the concept of health identity should be investigated in other groups, using both qualitative and quantitative methods. This should include further exploration of health identity as a construct that influences health behaviours and openness to change, the potential impact of life events such as pregnancy on health identity, and development of a tool to assess health identity. Further work should then aim to develop and test methods of supporting women to move towards the health-focused end of the health identity spectrum, as well as identifying intervention components that are particularly effective for women with different health identities.

5.5.3 Strengths and limitations

The methods employed in this study were appropriate and effective for addressing the research questions. Participants recruited to the interviews had all been recently pregnant and were exposed to HCS, making them ideally placed to discuss both the factors that influenced their diet

and physical activity in pregnancy and their engagement with a health behaviour change intervention. Addition of FG participants who were not part of SPRING and who were currently pregnant allowed for the inclusion of a wider range of perspectives and for the comparison of views between women who were currently pregnant and those who had been pregnant recently. The semi-structured interview guide approach allowed for the collection of a rich and unique dataset and the thematic analysis was conducted in accordance with established guidelines,[283] ensuring a rigorous and transparent process. However, it was only feasible to conduct two FGs in the available time frame; three were scheduled, but there were logistical barriers to conducting the final FG. As the findings from the two groups differed somewhat, it is possible that saturation was not reached and additional FGs would have yielded new findings.

While all participants represented the target population, there was limited diversity in the sample with regard to demographic characteristics as all women lived in and around Southampton, most were educated to degree level and most were White British. Furthermore, there were considerably fewer interview participants who fell towards the 'health-disengaged' end of the spectrum than the 'health-focused' end, which may limit the transferability of findings. However, by conducting FGs with women attending antenatal classes, some diversity in SES and ethnic background was introduced.

A potential limitation in any qualitative study is bias introduced by the assumptions and beliefs of the researcher.[283,284,311] In order to ameliorate this effect, the epistemological position informing this study was made clear from the outset and regular reflection on biases was part of the process. The interviews were always conducted with a second researcher who took the role of an observer and who could ask additional questions, thereby reducing the potential for bias that may arise if a single person were conducting the interviews without involvement of, or consultation with, other researchers. Similarly, two members of the research team double-coded a selection of interviews and coding was compared and discussed to ensure consistency. Finally, in examining the different themes and synthesising the results of the study, five members of the research team (TR, SS, WL, CV and MB) met to discuss the interpretation presented here. These steps served to lessen the potential for bias that may arise when a single researcher conducts a qualitative analysis.

In relation to the interview methods, the presence of an observer could have affected interview participants' responses. The observer in these interviews fulfilled two roles; it was deemed safer to travel to participants' homes with a second person, and the observer helped to ensure that all topics on the discussion guide were thoroughly addressed. It is possible that the presence of two researchers made some women to feel outnumbered or intimidated, and this may have encouraged socially desirable responses. While all participants were made aware that two

researchers would be attending the interview, and consented to this, it is important to consider that they may have given responses to appear more health-conscious. It was not necessary to conduct the FGs with an observer, and while some beliefs and attitudes differed between interview and focus group participants, there was no particular distinction with regard to socially desirable responses.

5.5.4 CAS framework

This chapter, comprising qualitative data from both interviews and FGs, has identified various factors that apparently influence diet and physical activity in pregnancy. Physiological pregnancy-specific factors that influence health behaviours, but are probably not amenable to change, include pain, fatigue, nausea and food cravings. Pregnancy may also introduce new motivation for improving health behaviours. Concern for the health of the baby, especially for nulliparous women, can be a powerful motivator to change, and may present an important opportunity for intervention. A woman's interest in her own health or weight is another important motivator for some, and interviews presented in this chapter suggest that interventions like HCS, which support women to reflect on and prioritise their own health, can increase this interest and help women to make a change. Therefore, a woman's focus on her own health is considered to be amenable to change through intervention. Social support has been identified in previous chapters as a factor that influences health behaviours, and this chapter provides further evidence that this is the case. Finally, health identity is a key concept that came out of this study, and is hypothesised to be associated with health behaviours as well as engagement with available support. All of these factors have been added to the CAS framework in **Figure 5.5**.

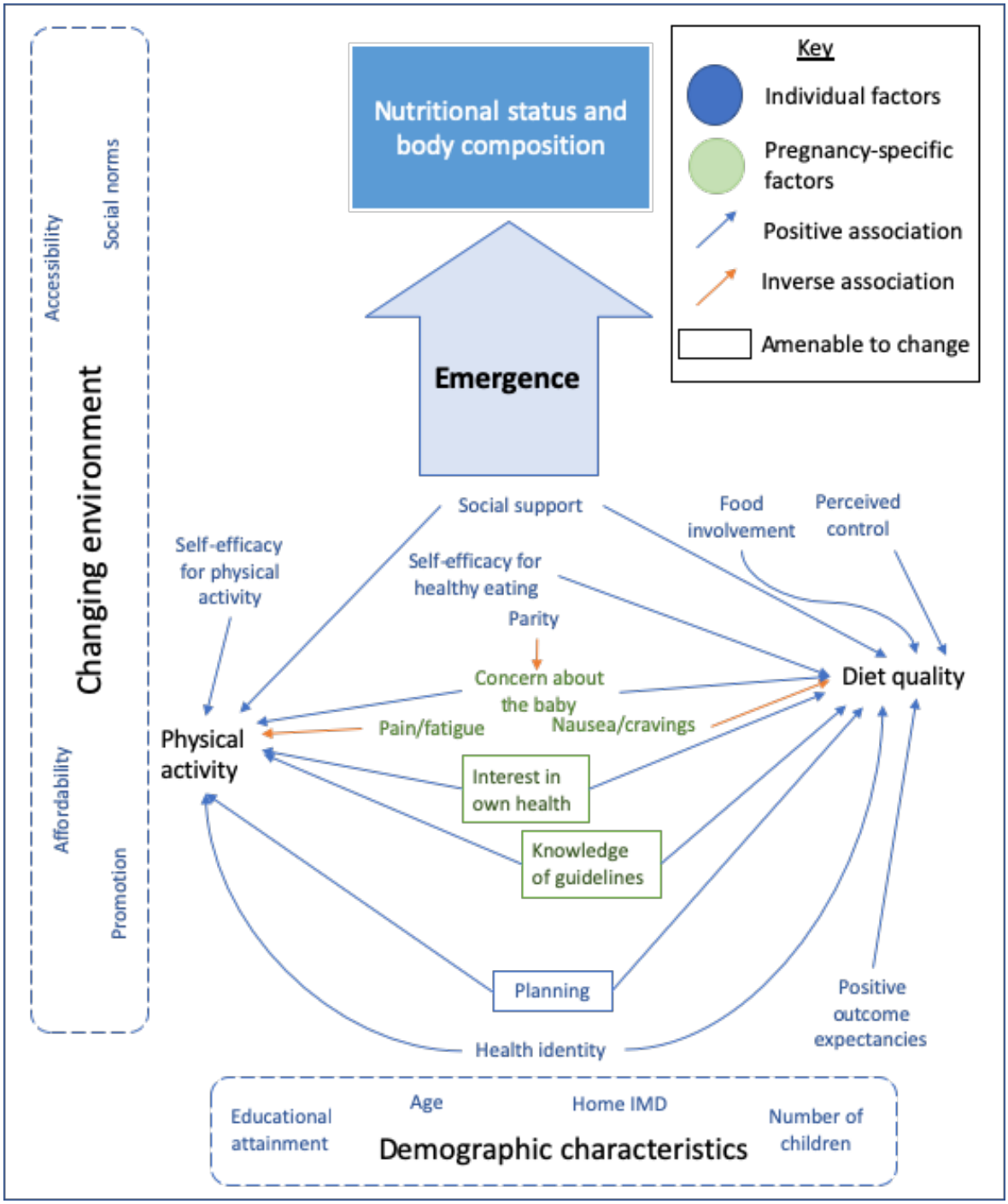


Figure 5.5 *CAS framework with factors identified from qualitative study added*

Chapter 6 Conclusions, implications and future directions

6.1 Introduction

This thesis aimed to address three research questions related to women's diet and physical activity behaviours in pregnancy in the context of a complex adaptive system.

Research question 1: How can we support women during pregnancy to improve their diet and physical activity behaviours?

Research question 2: What modifiable factors are associated with diet and physical activity, and changes to these behaviours, in pregnancy?

Research question 3: How can the factors that influence diet and physical activity in pregnancy be conceptualised as a complex adaptive system?

These questions were addressed through quantitative analyses of questionnaire data, a systematic review of intervention studies and a qualitative study with pregnant and recently pregnant women. Findings of these studies can be used to inform the development of future interventions, guide future research and support the development of a CAS framework to represent the factors that influence health behaviours in pregnancy.

6.2 Designing an intervention to improve diet and increase physical activity during pregnancy

6.2.1 Individual-level factors associated with diet and physical activity in pregnancy

Key individual-level factors associated with diet and physical activity in pregnancy were identified through this thesis, and can be seen in the final CAS framework (**Figure 5.5**). In Chapter three, factors associated with diet and physical activity were identified and included diet-specific self-efficacy, self-efficacy for physical activity, social support for purchasing fruit and vegetables, perceived control, outcome expectancies, total food involvement, and the cooking and eating-related sub-scale of food involvement (**Figure 3.3**). This analysis served as a useful starting point, but did not identify which of these factors were modifiable or which were associated with

changes in behaviour. To address these issues, Chapter four presented a systematic review of behaviour change interventions in pregnancy that aimed to identify which factors were modifiable and which were associated with changes in behaviour. This review found that women's knowledge of recommended guidelines was a modifiable factor that was also associated with a change in behaviour. Similarly, the degree to which women made diet and exercise plans was amenable to change, and was associated with changes in behaviour (**Figure 4.3**).

The qualitative study presented in Chapter five elicited a more in-depth understanding of important individual-level factors, some of which are not easily quantifiable (**Figure 5.5**). In particular, the physical changes that accompany pregnancy can make it difficult to be sufficiently active or to eat a healthy diet, and while these factors may not be modifiable, it is important to take them into consideration. Given these barriers, pregnancy may not be the ideal 'teachable moment' for all women and other points in the life-course should be considered. Indeed, there is currently considerable interest in intervening during the pre-conception period[178] and there is some evidence that interventions that begin before pregnancy can positively impact behaviours such as alcohol consumption, folic acid intake or eating a healthy diet.[312] However, this may prove difficult as pre-conception is not a well-defined period and pre-conception care often only applies to select high-risk groups.[312] Furthermore, approximately 55% of pregnancies in Britain are planned and unplanned pregnancies are associated with smoking, drug use and lower educational attainment.[313] This means that interventions that target women who are planning a pregnancy could miss the most vulnerable in the population and widen health inequalities.

Another factor that emerged in Chapter five was women's interest in their own health, which appeared to differ between women in their first pregnancy and those who had already had a baby. Finally, the concept of health identity was identified as an important factor that appeared to influence women's health behaviours and engagement with behaviour change support both during and beyond pregnancy. However, it is not yet known whether health identity is amenable to change through intervention, highlighting one area for future research.

6.2.2 Other factors that should be considered

In addition to the individual factors identified through the studies presented herein, it is important to consider wider influences on health behaviours and the impact of health inequalities. It is also necessary to recognise that, while diet and physical activity in pregnancy have a life-long impact on offspring health, there are many other behaviours that also influence development and for some women diet and physical activity will not be a priority.

6.2.2.1 Inequalities in health

As discussed in **Section 1.2**, it is important to consider inequalities in health and avoid widening them when implementing public health interventions. The Marmot Review points out that, even when individual-level interventions that aim to change specific behaviours are implemented, members of the middle class, who tend to be more healthy than those from more disadvantaged backgrounds, are more likely than the more deprived to take up these changes and inequalities are consequently widened.[5] Indeed, the plethora of challenges in addressing the inequalities in health is well-documented and clearly necessitates a whole-system approach, as has been discussed in previous chapters. This kind of approach will require work at every level of the social ecological model,[70] such as making changes to the environment, inducing shifts in social attitudes towards key health behaviours, improving social support for those who need it and implementing more effective behaviour change interventions for pregnant women.

One way of addressing inequalities that is proposed in the Marmot Review is to focus resources proportionately across the gradient in health inequality.[5] A successful and ethically sound intervention should support improved health across the whole population, but give more weight to the needs of the more deprived than the better-off. Chapter five showed that, while women who already felt they were being as healthy as they needed to be (health focused) did not engage with behaviour change support, there was an apparent gradient in engagement where those who were interested in their health engaged more than those who did not view their health as important (health disengaged). This range of engagement was not analysed with regard to SES due to the sample size in this qualitative study, but it is nevertheless apparent that uptake of healthier behaviours varies widely between women and interventions should be designed to target those who would benefit most from improving their diet and physical activity behaviours even though they may be reluctant to change. As discussed previously, this will likely require whole system shifts, including environmental and policy-level initiatives as an individual-level behaviour change intervention will probably not engage this group.

The tailored approach taken with HCS may be one way of focusing resources appropriately as it allows healthcare practitioners, such as midwives, to have a brief conversation with patients and identify their needs with regard to making a change in pregnancy. Those who are apparently meeting diet and physical guidelines may not require any further intervention while those who have the unhealthiest lifestyles may require more intensive support in the form of healthy conversations, patient education, more frequent contact or referral to other services. This approach appears to have been effective in an RCT of a lifestyle intervention to avoid GWG and postpartum weight retention. In this intervention, participants received individualised support

and feedback and those who were not meeting weight gain goals each month received additional support in the form of more frequent phone calls. The trial showed a significant reduction in both GWG and postpartum weight retention compared to standard care.[314] In the real world, this could be achieved by optimising the use of resources such that midwives' time is allocated in rough proportion to the identified needs of the pregnant women in their care. This is already done with other types of need in pregnancy. For example, women in their first pregnancy have more contact with their midwives than women in subsequent pregnancies[315] and after 24 weeks, healthy women are not seen as frequently as women with health concerns or complications.[316] Given the importance of diet and physical activity in pregnancy, which was described in Chapter one, it is reasonable to suggest that greater resource should be dedicated to women who require more support to meet diet and physical activity guidelines. This may mean that these women are given slightly longer antenatal appointments or receive supportive phone calls between appointments, or that they are referred to a dedicated service that delivers a tailored behaviour change intervention.

However, there are wider contextual factors that influence health behaviours that are not likely to be overcome with a face-to-face intervention alone. In the UK, austerity measures have had a disproportionate impact on the most deprived people – adversely affecting financial security and potentially jeopardising factors including secure housing, mental health and adequate nutrition.[317] Indeed, multiple studies show that food has become less affordable in the last decade[318] and that austerity measures put increasing strain on food budgets, compromising nutritional health.[319] Within this context of food insecurity and wide inequalities, encouraging women to be healthier and increasing their interest in improving their diet quality or increasing physical activity will not be sufficient to effect change in the most deprived women in the population. Rather, policy initiatives and environmental change are needed. For example, investment in food assistance programmes is often cost-effective, and has the greatest impact when targeted at the 'first 1000 days' window in early life.[320] Improvements in housing are also associated with better population health.[321]

Some of the ABMs described in Chapter six assessed how different interventions may impact on the discrepancies in health between affluent and deprived households.[176,187,189,193,196] These models suggested that attitudes towards walking or eating a healthy diet as well as the local environment were key factors that influenced inequalities in health behaviours. By finding ways of changing people's attitudes towards specific health behaviours, it may be possible to reduce inequalities in health behaviours. However, it is important to find ways of doing this that are particularly relevant to more deprived populations. In the ABM experiments described above, a reduction in health inequalities was at least partially achieved through modifying the local

environment to make walking more appealing in disadvantaged areas,[189] reducing the price of healthy foods,[196] improving education through investing in schools,[176] or by eliminating geographic segregation by SES.[196] These are all ambitious environmental-level interventions that would require extensive policy initiatives and multi-sectoral cooperation in the long term. By developing a detailed ABM to represent the factors that influence diet and physical activity in pregnancy that includes demographic factors like SES, virtual experiments could be used to ascertain how different intervention approaches may impact on health inequalities over time. The findings of such virtual experiments could then inform the implementation of interventions in the real world, reducing the probability that inequalities would be exacerbated.

Some of the findings of this work are based on data from relatively affluent women. In particular, SPRING participants who took part in the interview study were nearly all (16/17) White British, most (12/17) were educated to degree level or above and most (9/17) lived in the two least deprived quintiles based on home IMD. The focus group participants were more evenly distributed across the range of IMD and only half (5/10) were White British, but most (9/10) were educated to degree level or above. Thus, the findings about engagement with behaviour change support and the concept of health identity may not be generalisable to the whole UK population. However, the questionnaire data used in Chapter three to identify many individual-level factors associated with diet and physical activity were collected from women participating in the SIH study who attended Sure Start children's centres and this group was relatively deprived. Approximately 40% of SIH participants were in receipt of benefits and only 28% were educated to degree level or above. In order to develop an intervention that is appropriate for more deprived pregnant women, and thus does not widen inequalities, it will be necessary to explore concepts such as health identity, engagement with available support and attitudes towards behaviour change interventions with a wider range of pregnant women. It will also be important to test interventions with a range of women, especially those who are more deprived and whose diet and physical activity levels are the unhealthiest.

6.2.2.2 Other behaviours that influence health in pregnancy

The importance of diet quality and physical activity in pregnancy, and their impact on the life-long health of offspring, has been discussed extensively in Chapter 1. For some women, however, changing behaviours such as smoking or drinking alcohol should be prioritised as these can have serious consequences and cause a range of physiological and behavioural problems in offspring.[322,323] A meta-analysis of 14 observational studies found that children of mothers who smoked in pregnancy were more likely to be overweight between age 3 and 33.[324] Another systematic review included 172 observational studies and assessed the associations between

smoking in pregnancy and a range of birth defects. This review reported a significant positive association with heart defects, musculoskeletal defects, limb reduction, facial defects, eye defects, gastrointestinal defects and undescended testes.[325] Encouragingly, most people are aware of the harm that results from smoking in pregnancy, and prevalence has decreased to approximately 12% in the UK in recent years.[85] However, there are clear inequalities here as continued smoking during pregnancy is associated with lower educational attainment and various measures of low SES.[326,327] Women whose partners smoke are also significantly more likely to smoke in pregnancy, highlighting the role of social support.[327]

Alcohol consumption during pregnancy is also widely known to cause birth defects.[328] An analysis of cohort data from babies born in the 1990s in Australia found significantly increased odds of alcohol-related birth defects with heavy drinking in the first trimester compared with abstinence (adjusted odds ratio 4.5).[329] In addition, Fetal Alcohol Syndrome and a range of Fetal Alcohol Spectrum Disorders have been identified and well-described.[330-332] However, there is controversy around the effects of low or moderate alcohol consumption in pregnancy as some reviews have concluded that there is no significant association between moderate alcohol consumption and birth defects.[333,334] Still, health organisations such as the NHS [335] and CDC [336] have taken the position that there is no safe level of alcohol consumption and recommend that women abstain from any drinking from the periconceptional period through breastfeeding.

It is unclear how often and how much alcohol pregnant women drink. A cohort study in Australia found that as many as 37.6% of mothers drank alcohol during their pregnancy with some drinking on most days and a small proportion drinking three or more drinks per occasion. In this cohort, drinking alcohol in pregnancy was associated with older age, higher socioeconomic status and better health.[337] In a Danish cohort study, only 3% of women reported weekly alcohol consumption in pregnancy, but 35% reported binge drinking.[323] Encouragingly, the Health and Social Care Information Centre reports that, in 2010, of women in England who drank before pregnancy, 48% gave up drinking and a further 47% cut down.[115]

For women who are smoking or drinking alcohol during pregnancy, these are the behaviours that should be prioritised by health and social care services. Given the serious harm that can result from these behaviours, as well as the disparity with which they occur, investment in smoking and alcohol cessation programmes for pregnant women is vital. In these cases, asking women to make additional changes to their lifestyle may be overwhelming and unrealistic; interventions to improve diet or physical activity behaviours in this group would probably not be practical or cost-effective. However, the data collected for this thesis focused on diet and physical activity and none of the interview or focus group participants reported smoking during pregnancy, so

conclusions about these behaviours cannot be drawn. Future research with a more diverse study population is needed to better understand the circumstances that promote these dangerous behaviours in pregnancy, and how best to address them.

6.2.3 Key intervention components

This work was undertaken to inform the development of future interventions for improving diet quality or increasing physical activity during pregnancy and a number of likely intervention components have been identified. Firstly, there is evidence to support the inclusion of goal-setting and planning components. In particular, planning was identified as a modifiable factor that was associated with behaviour change in Chapter four. Chapter five found that the goal-setting support SPRING participants received as part of the healthy conversations initiated by the midwives was acceptable to most women and many felt it helped them maintain a healthy lifestyle. In addition, women should be encouraged to identify their own goals and make plans that fit their own circumstances, especially given the range of pregnancy-related barriers identified in Chapter five.

Improving women's knowledge of pregnancy-specific diet and physical activity guidelines may be an effective intervention component that motivates women to change. In Chapter four, pregnancy-specific health knowledge was identified as a modifiable factor that, when changed, was associated with significant behaviour change. The qualitative study in Chapter five showed that there was considerable variation in women's understanding of diet and physical activity guidelines in pregnancy and of the impact of these behaviours on their babies' health. It was also clear that, despite the extensive information included on commonly-used websites, many women were uninterested in accessing this information and preferred to receive advice from healthcare professionals or other trusted resources. Clearly, it is not sufficient to make information available; it may be more effective to deliver key health messages to pregnant women face-to-face as part of antenatal appointments. In order to ensure that clear and consistent messages are being conveyed in all appointments, some midwife training could be provided as part of intervention delivery. For example, a session on key diet and physical activity messages and how best to communicate them could be added to HCS or similar training.

While women's understanding of the impact of their diet and physical activity behaviours on their babies' development appears to be an important factor that influenced behaviour, there was also a clear role for women's interest in their own health. In Chapter five, interview participants often said that they were motivated to reach their diet or physical activity goals by their desire to stay healthy, maintain a healthy weight, or avoid getting fat. On the other hand, most of the FG

participants said that they were primarily motivated by their concern about their babies' development. While changes motivated by pregnancy will benefit the babies' development, they may be more likely to be temporary while supporting women to focus on their own health may encourage more lasting change. One difference between the interview participants and those who took part in the FGs was the exposure to the HCS intervention, suggesting that this kind of support helps women to consider and prioritise their own health. Therefore, it could be beneficial to include intervention components that encourage women to think about the long-term effects on their own health rather than only the more immediate impact of diet and physical activity on their baby's development.

The idea of supporting women to prioritise their own health is closely related to the concept of health identity, which emerged from the interview data in Chapter five. While further research is needed to understand this concept and how it influences women's health behaviours in pregnancy, it appears that women who view themselves as healthy people are more likely to maintain healthy diets and sufficient levels of physical activity in pregnancy. If a method for supporting a shift in health identity towards the 'health focused' end of the spectrum can be developed, this may be a powerful intervention component. However, it is not known if this is a realistic aspiration and it may be more feasible to tailor interventions to women's current health identity.

Indeed, there is a clear need to tailor interventions to women's individual needs. Existing interventions are usually only effective for a proportion of women and there is significant variation in engagement with available support.[267,275-277] Pregnancy introduces a unique opportunity to deliver a tailored face-to-face intervention to women as they have frequent contact with healthcare professionals. Simply providing advice or making information readily available online is clearly not sufficient to change most women's diet or physical activity behaviours. Rather, women have different priorities, attitudes, barriers and existing support and an intervention needs to be responsive to these differences.

All of these findings suggest that an intervention to support behaviour change in pregnancy should involve one-to-one support from a healthcare professional such as a midwife. Within routine antenatal appointments, women should be given information about the importance of healthy diet and physical activity behaviours and how these behaviours can influence both the woman and her developing fetus. They should also be encouraged to set realistic and measurable goals, such as eating at least three servings of vegetables per day or walking for 30 minutes every day. Progress toward reaching these goals should also be monitored by discussing them in every

subsequent antenatal appointment. Women could also be encouraged to self-monitor their progress using existing tools, such as readily-available apps.

The exact content and intensity of the intervention should be adaptable based on women's individual circumstances and their interest in improving their health. Women will experience different barriers to change, and will have different things that they would like to change. Some may find it easier or more beneficial to improve their diet quality while others may prefer to take up an antenatal exercise class and either of these changes should be supported and encouraged. Similarly, a midwife may find that one patient only needs to be asked briefly about her goals and progress toward reaching them while another patient is struggling and requires a more in-depth discussion and support to overcome barriers.

It may not be practical or cost-effective to provide this kind of intervention for all pregnant women. For example, women who are smoking during pregnancy should be referred to smoking cessation services and any behaviour change support should focus on quitting smoking, so an intervention to change other behaviours would not be feasible. On the other hand, women who are already very healthy and 'health-focused' will probably not significantly benefit from additional behavioural support.

All of these services must be implemented within the context of health and social care policies that support good health in pregnancy. Particularly for women who are 'health-disengaged' and are not interested in improving their health, a one-to-one approach may not be effective or cost-effective on its own. If this is the case, then only implementing an individual-level intervention could widen health inequalities by disproportionately benefitting those who are already somewhat motivated to change. Indeed, a multi-component approach that includes structural change is the most promising for effecting improvements in health that do not exacerbate inequalities.[310,338] Therefore, as discussed in **Section 6.2.2.1**, investment in programmes that improve accessibility to healthy food and other services must be part of a comprehensive health improvement initiative.

6.3 The CAS of factors that influence diet and physical activity in pregnancy

This thesis also set out to conceptualise the factors that influence diet and physical activity in pregnancy as a CAS, and a CAS framework has been developed based on the findings from Chapters three through five (**Figure 6.1**). The framework aims to represent the key features of a CAS including relationships between system components and emergent outputs over time. It is acknowledged that contextual and demographic characteristics must be considered, and these factors are also included in the framework as they should be included in an ABM to represent this system.

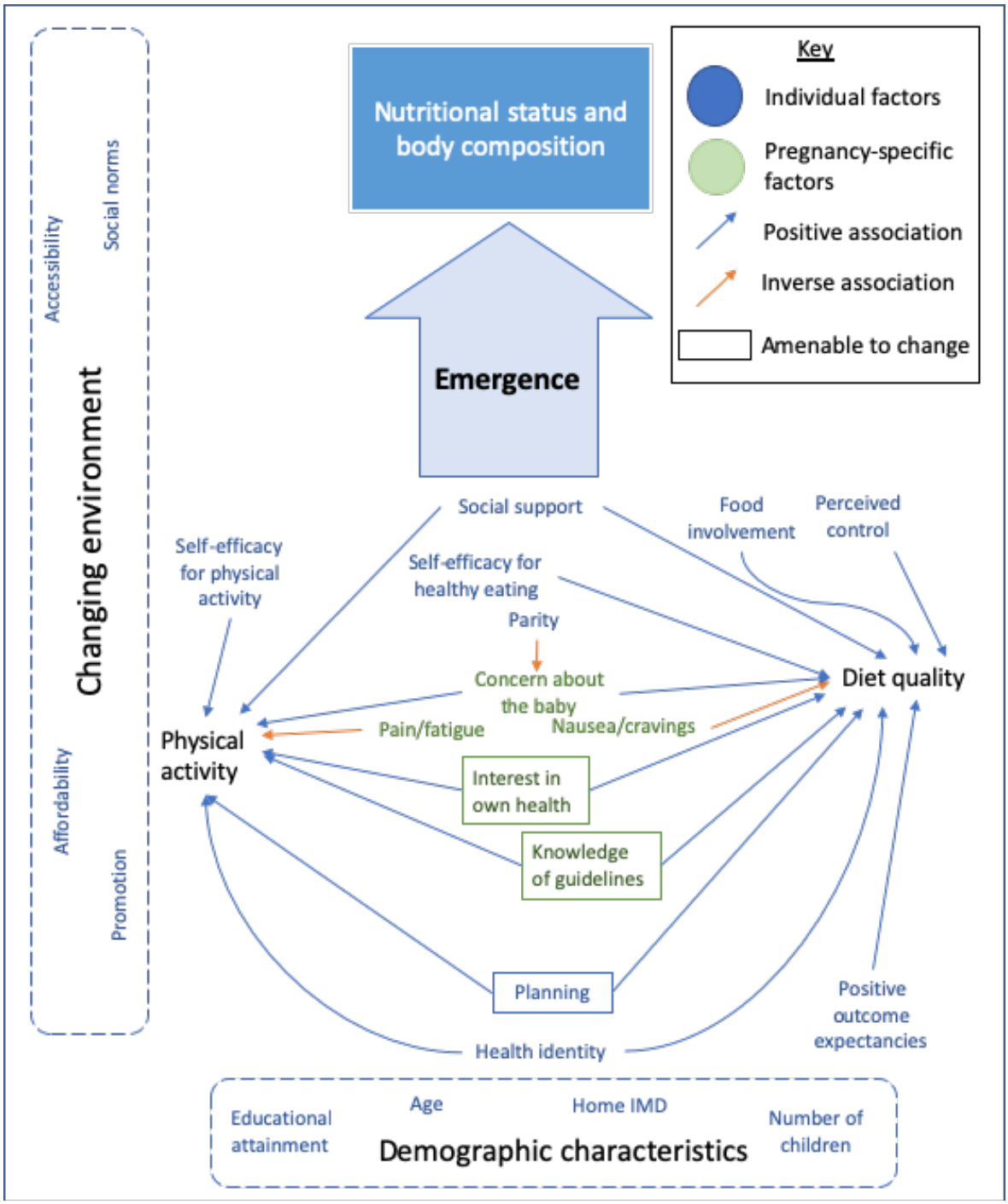


Figure 6.1 *CAS of factors that influence diet and physical activity in pregnancy*

As described in Chapter two, ABMs have been used in public health research to model primarily environmental influences on health behaviours.[177,179] These have examined, for example, neighbourhood features and their influence on walking behaviour[189,193-195] as well as food environments and their influence on diet quality.[185-187] Such models can inform policy by identifying environmental modifications that could have a meaningful impact on population health. However, the environment is not the only influence on individuals' diet and physical activity behaviours and, in contrast to most studies that have used ABMs, this thesis has focused

on individual-level factors. Furthermore, pregnancy and the pregnancy-specific experiences that influence behaviour have not previously been conceptualised as a CAS. Given that many behaviour change interventions are aimed at individuals, and that pregnancy is a time when women have more contact with healthcare practitioners, there is a need to better understand the individual-level components of the system that influences diet and physical activity during pregnancy. Furthermore, as discussed in Chapter five, women respond differently to behaviour change interventions, so a population-level (environmental) approach is only likely to support some women to change and tailored individual interventions need to be designed to meet women's varying needs and preferences. For these reasons, there are potential benefits to using a modelling approach such as an ABM to gain a mechanistic understanding of the way key individual factors influence women's engagement with behaviour change support and their likelihood to make a change during pregnancy.

While an operational model cannot yet be designed, the findings from this thesis can be used to inform the development of an ABM. The statistical data presented in Chapters three and four provide insight into which individual-level factors may be most important in influencing diet and physical activity in women of childbearing age, but do not show how different factors may interact or whether there are feedback loops involved. This gap in knowledge could be addressed through analysis of further datasets and through consultation with experts, and the theoretical mechanisms could be investigated and tested through an iterative programming process where model outputs are compared with observational data.[339] Similarly, the qualitative data analysed in Chapter five provides a more detailed understanding of factors that influence women's health behaviours in pregnancy, including pregnancy-specific experiences. This analysis also explored women's engagement with sources of behaviour change support in pregnancy. While clearly important to the CAS, many of these factors are not readily quantifiable, so assumptions would need to be made about the extent to which each of these factors influenced diet and physical activity, and these assumptions would need to be assigned quantitative values. Again, this could be done through consultation with experts, and by testing various versions of the model being developed.

Extensive computing time and expertise are required to programme a simple model, iteratively test various changes to the model, make judgements about the plausibility of model parameters and agent behaviours, and finally produce a sufficiently complex ABM that can be used to inform intervention and policy development. This kind of programming work is outside the scope of this thesis, and would comprise a significant project in its own right. Therefore, this section aims to describe how the findings from this thesis could be used to inform the development of an ABM.

In order to increase transparency and replicability in designing ABMs, a framework called the ODD (Overview, Design concepts and Details) framework has been developed.[340] This aimed to encourage more complete reporting of ABMs by providing a detailed list of questions to describe all facets of the model design. While useful, the ODD framework was considered by some to be insufficient for describing individual decision-making as it became a more common component of ABMs, so a more detailed framework (ODD+D) was published in 2013, which added items related to Decision-making.[341] The ODD+D framework can be used to guide the development of ABMs, and to provide a template for reporting them in sufficient detail. **Table 6.1** shows a summarised version of the framework presented in the original publication. Some of the details are specific to programming of the model, but many of the details are focused on the agents and parameters that should be built in.

Table 6.1 *Summary of ODD+D Framework elements*[341]

Structural elements		Key points
Overview	Purpose	Purpose and intended audience for the model
	Entities, state variables and scales	What kind of entities are in the model? How are these entities characterised? How is space represented in the model?
	Process overview and scheduling	What does what, and in what order?
Design concepts	Theoretical and empirical background	General concepts, assumptions and data upon which the model is based
	Individual decision making	What are the levels of decision-making? What factors influence decision-making? How do time, space and social interaction influence decision-making? How is uncertainty included in decision-making?
	Learning	How is learning included in the decision-making process?
	Individual sensing	What factors and variables can agents sense to inform their decision-making?
	Individual prediction	Do agents make predictions about the future? If so, what information do they use to make predictions?
	Interaction	How do agents interact with one-another?
	Collectives	Do agents form collectives? If so, how?
	Heterogeneity	How do agents differ between one-another?
	Stochasticity	How is randomness incorporated into the model?
	Observation	What output data are collected from the model? What characteristics emerge from the model?
Details	Implementation details	Model implementation and availability details
	Initialisation	State of agents and parameters at model initialisation
	Input data	Input from external sources
	Sub-models	Description of any sub-models

Findings from this thesis and the resulting CAS model are now used to address some of the components of the ODD+D framework.

6.3.1 Overview

The purpose of the ABM is to inform the development of more effective interventions in pregnancy by identifying key individual-level factors that, when changed, support a meaningful change in diet or physical activity. Women are likely to be the only agent type in the ABM and demographic characteristics identified in **Figure 6.1** should be included as individual variables. Home IMD could be represented spatially, either using GIS data from Southampton or by

designating different IMD sections on a grid. The other demographic characteristics could be randomly assigned according to observed distributions in the population. Pregnancy needs to be represented in this model, and one way to do this would be to specify that a proportion of randomly-selected agents become pregnant at regular intervals, and then stay pregnant for nine months. During these nine months, the pregnancy-specific factors identified in the model: concern about the baby; pain; fatigue; nausea; interest in own health; and knowledge of pregnancy-specific guidelines would influence diet and physical activity. At the end of the nine months, the woman's number of children would increase by one and the pregnancy-specific factors would no longer be involved in determining her behaviours.

6.3.2 Design concepts

The ABM should be based on the CAS framework developed through empirical quantitative and qualitative research rather than on a particular theory of behaviour. **Figure 6.1** shows the individual-level factors that have been identified through this thesis that influence diet quality and/or physical activity, including the pregnancy-specific factors that may be most important. However, the framework needs to be developed further before it can be used for designing an ABM.

Firstly, the model presented here (**Figure 6.1**) shows the hypothesised relationships between the individual-level factors and diet and/or physical activity. Further research is needed to model the relationships *between* the individual factors. In order to represent a CAS, feedback loops and complex relationships between elements in the system are necessary.[342]

Secondly, the role of pregnancy and its impact on factors such as self-efficacy and outcome expectancies needs to be elucidated. While pregnancy-specific factors that influence health behaviours during pregnancy have been identified (shown in green in **Figure 6.1**), it is not known whether the other factors (shown in blue) are impacted by pregnancy. If they are, then values for these factors should change when agents enter into pregnancy. This question could be addressed using a longitudinal study that begins before pregnancy and collects data on these factors at multiple time points before and during pregnancy.

Finally, it is necessary to specify the outputs of the model. Diet quality and physical activity have been named as the behaviours of interest, but a specific measure needs to be used to model these behaviours. The primarily environmental studies described in the previous section used measures such as choosing to use active transport[194] and visiting healthier food outlets[187,188] to represent physical activity and diet, respectively. This ABM, however, is not intended to assess environmental interventions, so different measures should be used. To represent diet quality, the

prudent diet score described in **Section 3.2.2** may be appropriate. In this case, each agent would be assigned a prudent diet score, and this score may change as the model runs in response to changes within the system. Various methods have been used to assess levels of physical activity during pregnancy[119] and it may be necessary to review existing evidence to identify the best way to represent physical activity in the ABM.

Once these design concepts have been finalised, it will be possible to specify how each of the key individual-level factors change over time and how these changes lead to changes in health behaviours. From there, the modeller can run experiments and make decisions about the remaining details in the ODD+D framework, including learning, sensing, and interaction between agents.

6.3.3 Strengths, limitations and challenges associated with using ABMs in diet and physical activity research

The examples of ABMs described in **Section 2.7** show how these models are a potentially powerful tool for gaining a more detailed understanding of factors that influence diet and physical activity in the population as well as the potential size of impact of a given intervention over time. By modelling individuals or households as agents that interact with their environments and with one another, and by incorporating the capacity for individuals and their environments to change over time, researchers can conduct virtual experiments that aim to reflect real-world processes. These experiments can be conducted at minimal cost and in a relatively short time frame compared to traditional trial designs in the real world.

Despite these advantages, agent-based modelling in public health is a relatively new field and a number of limitations are apparent.[342,343] As can be seen in many of the models described, experiments often give expected results that are predictable from model inputs rather than identifying unintended consequences, suggesting that ABMs to describe influences on diet and physical activity have not been used to their full potential. Identification of unintended consequences has, however, been achieved in other ABMs of health behaviours. An ABM called SimDrink[344] was designed to test the effects of different public transport and venue lockout policies on alcohol-related harms in Melbourne, Australia.[345] In the modelling experiments, the effects of some of these interventions were simply to displace alcohol-related harms from public to private venues, and in some cases these harms increased while other harms were reduced; effects which likely would not have been captured using models that did not incorporate key features of a CAS.

The usefulness of ABMs in analysing the potential unintended impacts of tobacco policies has also been identified. The IOM Committee on the Assessment of Agent-Based Models to Inform Tobacco Product Regulation published a detailed report in which the probability of unintended consequences of policy is discussed.[346] The authors acknowledge that individuals and industry respond to policies in different ways, leading to both positive and negative feedback loops that may result in unintended consequences or make interventions less effective. This, they say, is one reason to favour complex systems models over the accepted 'gold standard' RCT.[346] Clearly, ABMs have the potential to capture unintended consequences related to human behaviour, but no ABM has yet captured key mechanisms that may show such consequences related to diet or physical activity. As discussed in **Section 2.6**, a number of modelling strategies taking a complex systems approach to analysing the impacts of the 'sugar tax' may identify unintended consequences, such as changes in industry behaviour or public attitudes.[174] Studies like that one may help to inform the development of more comprehensive models related to health behaviours, including future ABMs.

A key limitation associated with this approach is that available data are often limited in their applicability to designing an ABM.[179,347] Data that are considered to be of the highest quality often come from RCTs, which aim to test the effect of changing one factor in a system while holding all other factors constant.[347] This approach does not allow for the exploration of how one factor in a system may impact on other factors, or whether one factor in the system is dependent on changes in other factors. Furthermore, the studies upon which these models are built, whether intervention trials or observational studies, have usually not assessed causal mechanisms underlying the relationship between exposure and outcome, so their data may not be transferrable to a complex model such as an ABM.[179] As a result, designing ABMs is often reliant on assumptions about which factors are important, how factors interact and how behaviour might change as a result. Indeed, it can be very difficult to correctly parameterise, validate and test new models.

Another limitation, which applies to all quantitative analysis methods, is that non-quantifiable factors are not easily incorporated into an ABM. While some modellers tend to focus on quantitative data in ABMs, the value and importance of qualitative data has been highlighted.[348] Implementation scientists Northridge and Metcalf discuss 'best principles' for using systems science, and propose that a good model must 'pay attention to what is important, not just what is quantifiable.'[348] This principle highlights both a strength and a key challenge of taking a complex systems approach to analysing health behaviours. From the research presented in this thesis, it is clear that some of the key individual-level factors influencing diet and physical activity during pregnancy are not easily quantifiable, such as health identity and concern about the baby's

development. These factors are likely to be important in influencing the overall functioning of the system, so the capability of a systems model to take these factors into consideration is an important advantage. However, in order to programme an ABM, it is still necessary to assign quantitative values to these factors and the way they interact with other elements of the system. Therefore, the modeller must make informed judgements and engage in a long process of trial and error where modelling becomes an art as much as a science.[179] This was done in one of the models described in Chapter 2 where it was assumed that a health promotion campaign would increase the social norm of eating fruit and vegetables by 10%.[188] Indeed, in designing an ABM it is necessary to make judgements about the plausibility of model parameters as well as agents' likely behaviours. One review points out that ABM experiments may not be reliable with regard to their quantitative outputs because values used to design the model cannot always be based in evidence.[179] Therefore, some experiments designed to test the potential impacts of interventions may be useful for comparing the probable advantages and disadvantages of different approaches rather than predicting real-world outcomes.

Another challenge when designing an ABM is in striking the correct balance between simplicity and complexity.[347] Including too few elements will result in a model that does not represent the interactions and feedback loops that exist in the real world. On the other hand, models that are overly complicated will have too many feedback loops, too many interactions and potentially too many outcomes. This makes it impossible to gain useful insights about key system components and how they function.[347] The recommended approach to finding this balance is to begin with a simple model and slowly add in complexity that contributes to the usefulness of the model.[179] This should be done iteratively through trial and error as the model is being programmed, and through consultation with experts who can provide insight and assess face validity of model parameters.[179]

Once designed, validation of ABMs presents an additional challenge.[339] One reason for this is that, in order to validate a model, data that are independent from the data that informed the model should be used.[179] When there is a paucity of data that are readily applicable to these systems models, it can be impossible to validate an ABM against a separate dataset.[179] Furthermore, there is a general lack of standard methodology for designing, calibrating and validating ABMs for application to public health problems. While useful methods are slowly being developed and used by specialists, usually in collaboration with computer scientists or economists, most public health scientists and practitioners are not trained in novel trial designs or in complex systems analyses such as ABMs.[179,347] Indeed, it has been argued that if public health research is to advance in its understanding of real-world systems, public health training should incorporate key CAS principles and necessary skills for modelling these systems.[179]

6.4 Conclusion

As the prevalence of obesity and related NCDs continues to rise across the UK, there is an urgent need to develop and implement more effective interventions.[1,2] One way of improving population health is to set people on a healthier trajectory from before birth by supporting women to improve their nutritional status and body composition in pregnancy.[12-15] The complexity of factors that influence diet and physical activity in pregnancy, and the variation in women's engagement with behaviour change interventions, suggest that individual tailored support is necessary to elicit meaningful change. The frequency with which women see their midwives in pregnancy presents a unique opportunity to deliver this kind of intervention, as does the 'teachable moment' that pregnancy is thought to represent.[114] This is the first research project that has analysed the individual-level factors that influence diet and physical activity within the context of a CAS, and the first to focus on pregnancy. Through three different studies, this work has identified a number of factors that influence diet and physical activity in pregnancy, some of which appear to be modifiable through intervention, and integrated these into a CAS framework that can be used to inform intervention development. Furthermore, directions for future research have been delineated and further development of the CAS framework will both identify more opportunities for intervention and support the development of ABMs that can be used for hypothesis testing and for conducting virtual experiments. By applying the knowledge gained and taking this work forward, there is huge potential to improve pregnant women's health and the health of the next generation.

Appendix A Psychological scales used in SIH

General self-efficacy

Please say how much you agree or disagree with these statements depending on how true they are for you.

	Strongly disagree	Disagree	Agree	Strongly agree
I can always manage to solve difficult problems if I try hard enough				
I can find a way to get what I want even if someone is trying to stop me				
It is easy for me to stick to my aims and reach my goals				
I am calm when things are difficult because I know I can cope				
If I am in trouble I can usually find a way out				

Self-efficacy for healthy eating

Please say how much you agree or disagree with these statements about healthy eating depending on how true they are for you.

I could stick to eating healthy foods even if…	Strongly disagree	Disagree	Agree	Strongly agree
I need a long time to build new habits				
I have to try a few times before I succeed				
I have to rethink my whole diet				
I don't receive much support from others when I start out				
I have to make a detailed plan				

Social support for purchasing fruit and vegetables

How often do members of your family…

	Never	Rarely	Sometimes	Often	Very often
Approve when you buy fruit, fruit juice or vegetables					
Ask you to buy fruit, fruit juice or vegetables					
Remind you to buy fruit, fruit juice or vegetables					
Buy fruit, fruit juice or vegetables					
Talk to you about buying fruit, fruit juice or vegetables					

Appendix A

Perceived control

Please say how much you agree or disagree with these statements depending on how true they are for you.

	Strongly disagree	Disagree	Agree	Strongly agree
I feel that what happens in my life is often determined by factors beyond my control				
I often have the feeling that I am being treated unfairly				
Keeping healthy depends on things that I can do				
Over the next 5-10 years I expect to have many more good things than bad things happen				
There are certain things I can do for myself to reduce the risk of heart disease				
In the past 10 years, my life has been full of changes without my knowing what would happen next				
There are certain things I can do for myself to reduce the risk of cancer				
At home I feel I have control over what happens in most situations				
I gave up trying to make big improvements or changes in my life a long time ago				

Outcome expectancies

Please say how much you agree or disagree with each of these statements about eating healthy food.

I know that if I eat healthy foods…	Strongly disagree	Disagree	Agree	Strongly agree
I'll feel physically more attractive				
I won't have any weight problems				
It will be good for my blood pressure				
I'll feel happier				
It will be good for my cholesterol levels				
Other people will admire my willpower				

Self-efficacy for physical activity

Please could you say how much you agree or disagree with these statements about exercising depending on how true they are for you

I could stick to an exercise routine even…	Strongly disagree	Disagree	Agree	Strongly disagree
When I have worries and problems				
If I feel depressed				
When I feel tense				
When I am tired				
When I am busy				

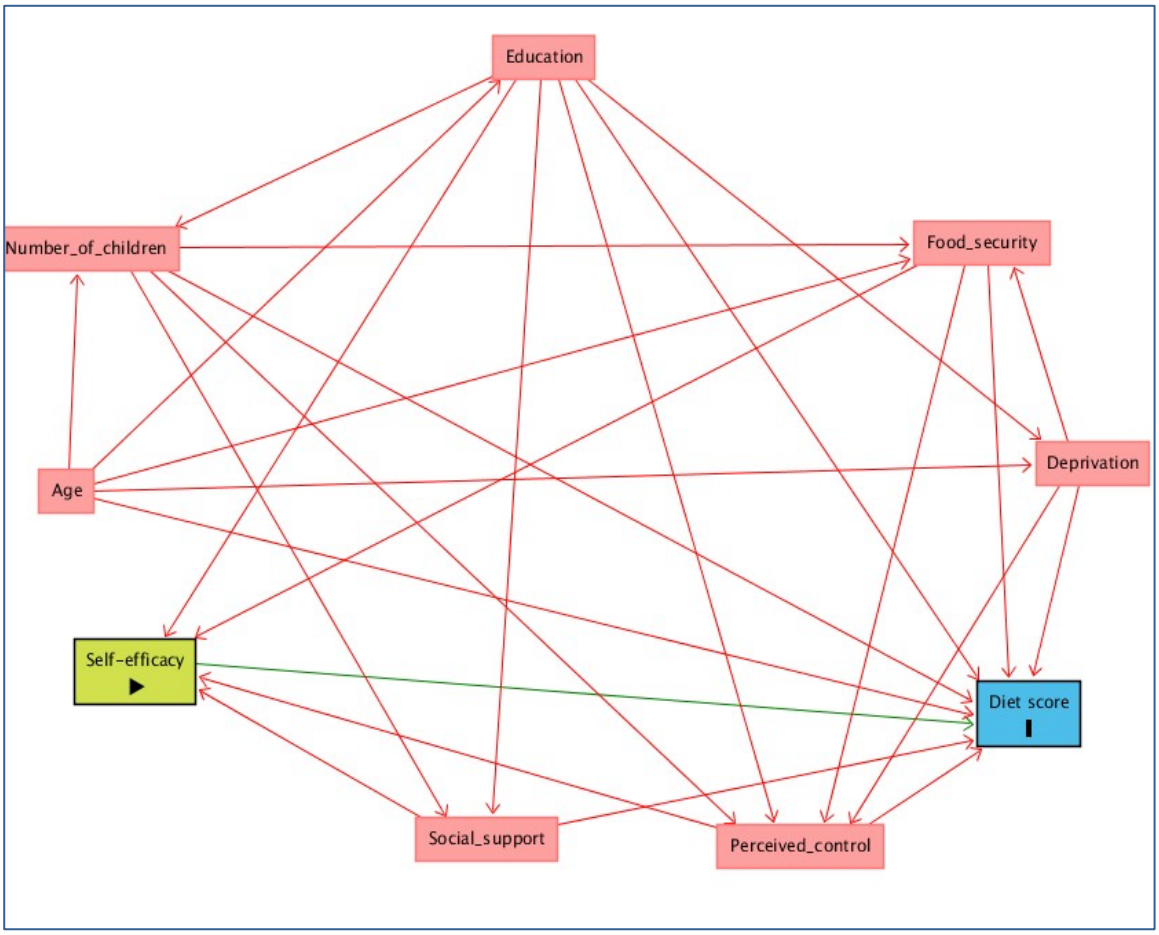
Food involvement

We want to know how you think about what you're going to cook and eat, and what you feel about preparing food.
Please say how much you agree or disagree with each of these statements.

	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
I don't think much about food each day					
Cooking or barbequing is not much fun					
Talking about what I ate or am going to eat is something I like to do					
Compared with other daily decisions, my food choices are not very important					
When I travel, one of the things I anticipate most is eating the food there					
I do most or all of the cleaning up after eating					
I enjoy cooking for others and myself					
When I eat out, I don't think or talk much about how the food tastes					
I do not like to mix or chop food					
I do most or all of my own food shopping					
I do not wash dishes or clean the table					
I care whether or not a table is nicely set					

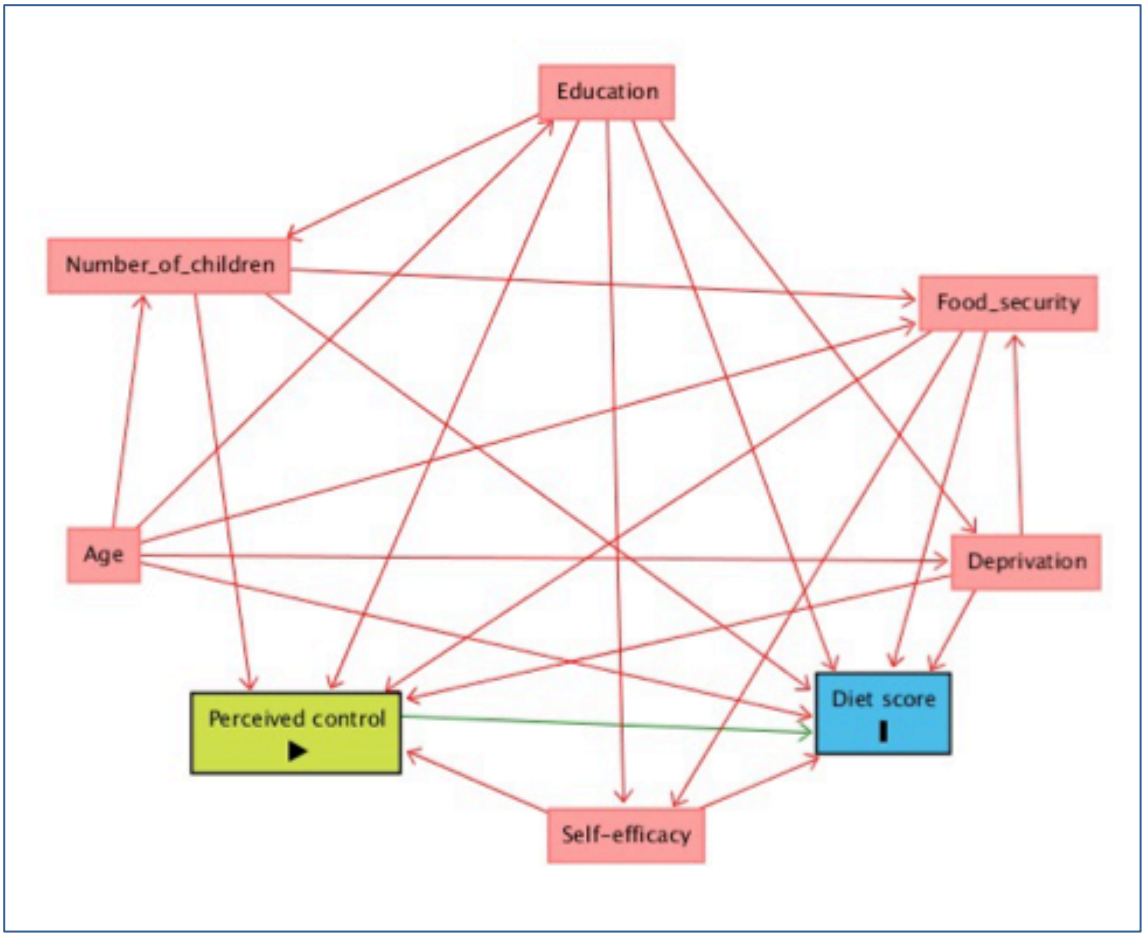
Appendix B Directed acyclic graphs

Self-efficacy and diet score



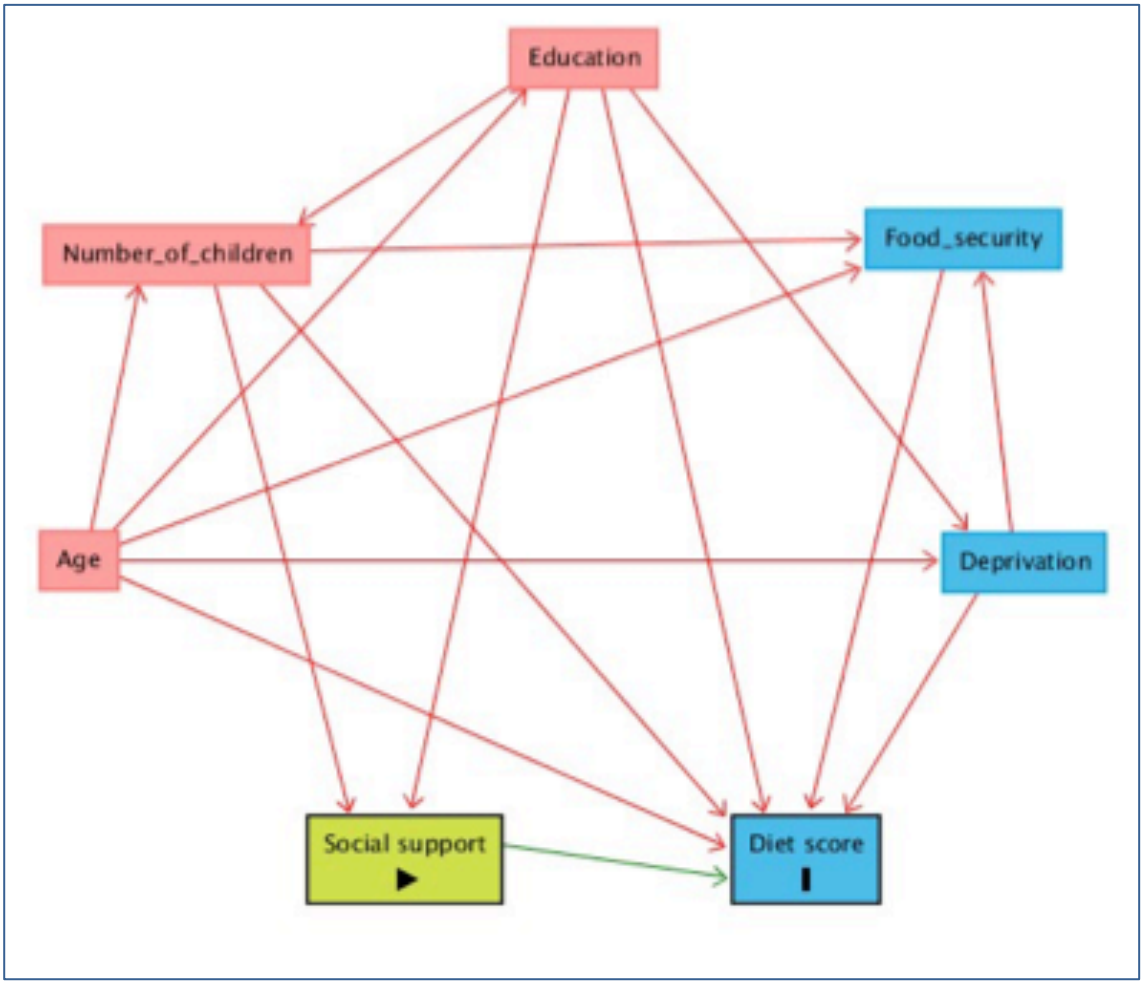
Confounders: Educational attainment, Food security, Perceived control, Social support

Perceived control and diet score



Confounders: Deprivation, Educational attainment, Food security, Number of children, Self-efficacy

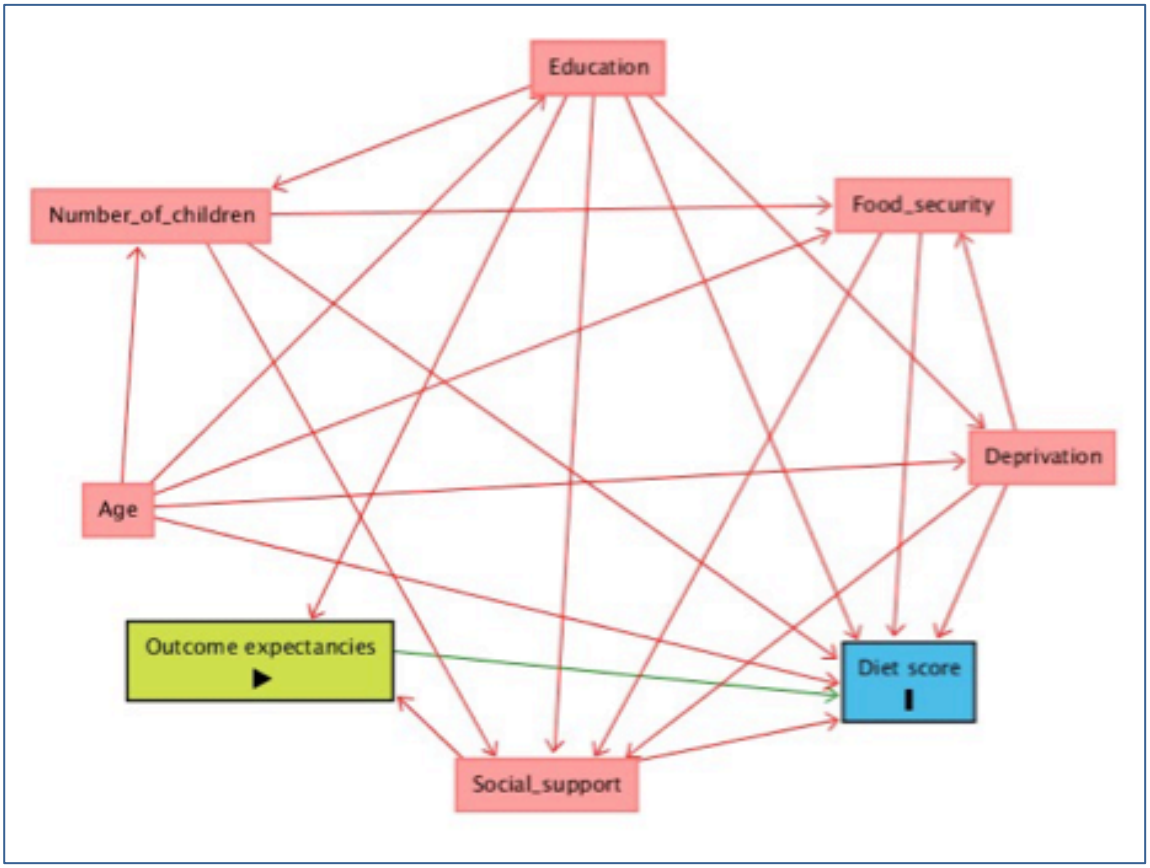
Social support and diet score



Confounders: Educational attainment, Number of children

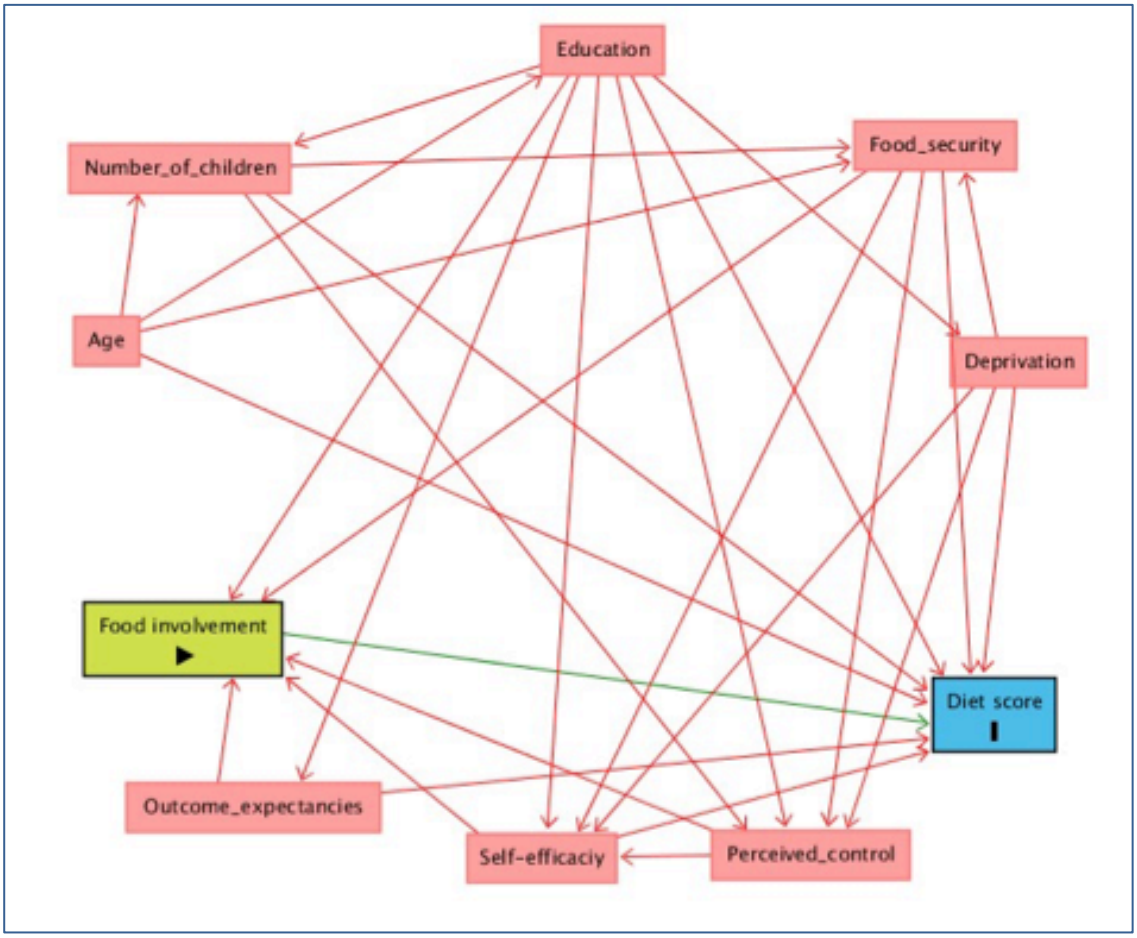
Appendix B

Outcome expectancies and diet score



Confounders: Educational attainment, Social support

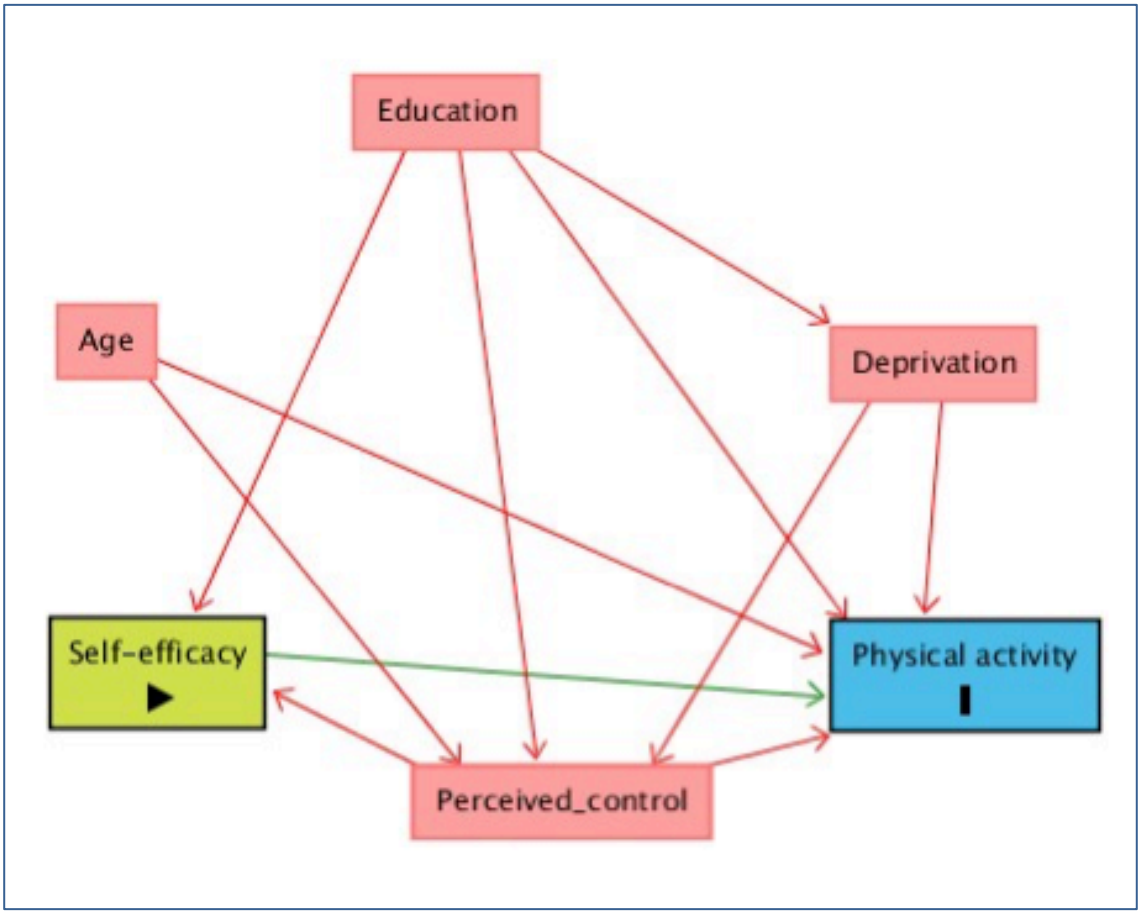
Food involvement and diet score



Confounders: Deprivation, Educational attainment, Food security, Number of children, Outcome expectancies, Self-efficacy

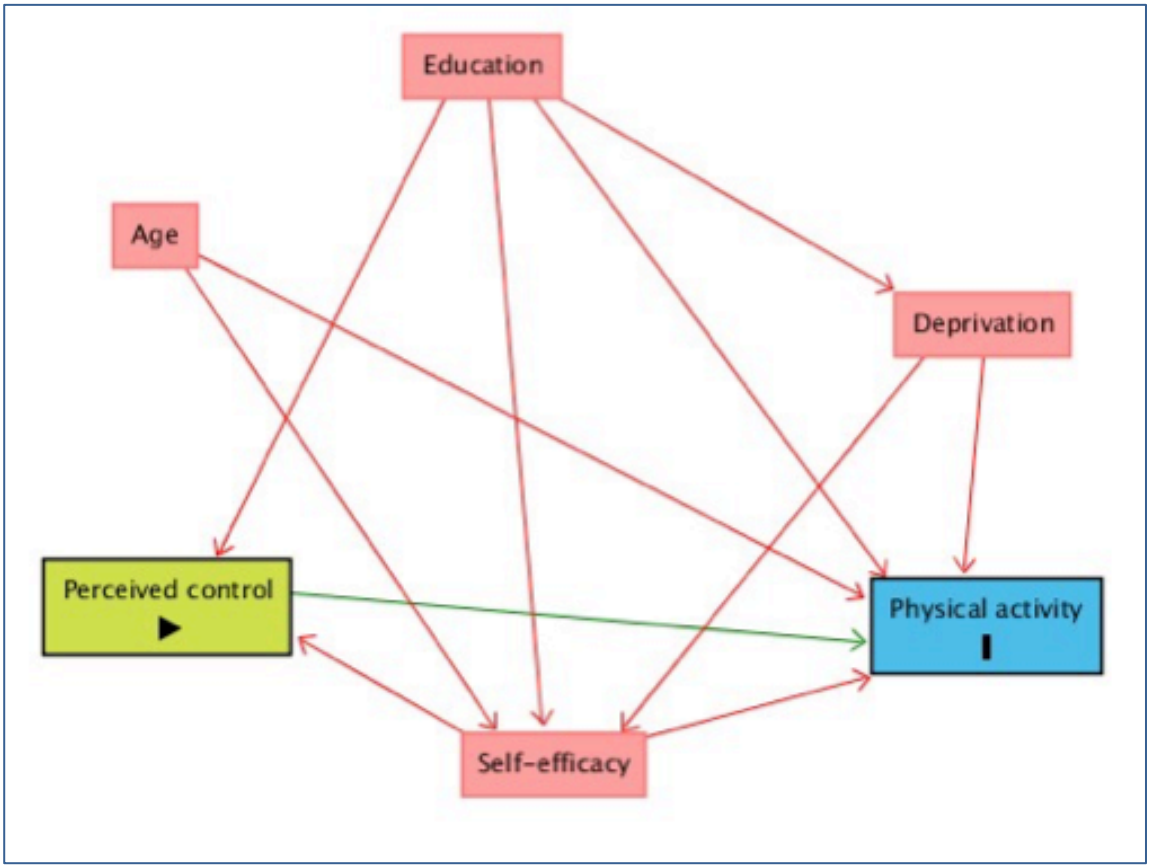
Appendix B

Self-efficacy and physical activity



Confounders: Educational attainment, Perceived control

Perceived control and physical activity



Confounders: Educational attainment, Self-efficacy

Appendix C Systematic review search strategy

Medline

1. Pregnancy/ or Pregnant Women/
2. Maternal Health Services/ or Prenatal Care/
3. gestation*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
4. antenatal.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
5. Postpartum Period/ or Postnatal Care/
6. 1 or 2 or 3 or 4 or 5
7. Consum*.mp.
8. Exp Diet/
9. Nutrit*.mp.
10. Eating/
11. Health* eating.mp.
12. Micronutrients/ or Energy Intake/
13. "Diet, Food, and Nutrition"/ or Food/
14. 7 or 8 or 9 or 10 or 11 or 12 or 13
15. Physical activit*.mp.
16. Exercise/ or Exercise Therapy/
17. Sport/
18. Fit*.mp.
19. Yoga/
20. Walk*.mp. or Walking/
21. Swimming/ or Swim*.mp.
22. Sedentary lifestyle/ or Sedentar*.mp.
23. 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22
24. 14 or 23
25. 6 and 24
26. Pragmatic Clinical Trial/ or exp Clinical Trial/ or Randomized Controlled Trial/ or trial.mp. or Controlled Clinical Trial/
27. Intervention.mp
28. Trial.mp.
29. 26 or 27 or 28
30. 25 and 29

Appendix C

Embase

1. Exp Pregnancy/
2. Pregnant woman
3. Prenatal care/ or prenatal.mp. or prenatal period/ or prenatal exposure/
4. Antenatal.mp.
5. Gestation*.mp.
6. Postpartum.mp.
7. Postnatal.mp. or postnatal care/
8. Maternal.mp. or maternal behaviour/ or maternal nutrition/ or maternal health service/ or maternal care/
9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10. Consum*.mp.
11. Exp diet/ or unhealthy diet/ or healthy diet/ or diet therapy/
12. Nutrition/ or nutritional status/ or food/ or dietary intake/
13. Eating/
14. 10 or 11 or 12 or 13
15. Exp exercise/ or fitness/ or exp physical activity / or physical activit*.mp.
16. Sport/
17. Yoga/
18. Walk*.mp.
19. Swim*.mp.
20. Sedentary lifestyle/ or health behaviour/
21. 14 or 15 or 16 or 17 or 18 or 19 or 20
22. 9 and 21
23. "clinical trial (topic)"/ or trial.mp. or controlled clinical trial/
24. Intervention.mp.
25. 23 or 24
26. 22 and 25

Web of Science Core Collection: Social Sciences Citation Index

1: Topic: (pregnan*) OR Topic: (matern*) OR Topic: (prenatal) OR Topic: (antenatal) OR Topic: (postpartum) OR Topic: (postnatal)
2: Topic: (gestation*)
3: 1 OR 2
4: Topic: (consum*) OR Topic: (diet*) OR Topic (*nutrient* OR nutrition) OR Topic: (eating) OR Topic: (food*) OR Topic: (intake)
5: Topic: (physical* NEAR/2 activ*) OR Topic: (exercise*) OR Topic: (sport) OR Topic: (fit*) OR Topic: (yoga) OR Topic: (swim*) OR Topic: (walk*) OR Topic: (sedentary*)
6: 4 OR 5
7: Topic: (RCT OR "clinical trial" OR randomi?ed NEAR/2 trial) OR Title: (trial) OR Topic: (intervention)
8: 3 AND 6 AND 7

CINAHL

S1: (MH “prenatal nutritional physiology”) or (MH “Prenatal care”) or “prenatal”
S2: (MH “expectant mothers”)
S3: pregnan$
S4: gestation
S5: (MH “Postnatal Period”) OR (MH “Postnatal Care”) OR “postnatal”
S6: S1 or S2 or S3 or S4 or S5
S7: consum$
S8: (MH “Maternal Nutritional Physiology”) OR (MH “Nutritional Support”)
S9: (MH “Diet+”)
S10: (MH “Eating”) OR (MH “Eating Behavior”) OR (MH “Food Habits”)
S11: (MH “Food+”) OR (MH “Food Preferences”) OR (MH “Food Habits”)
S12: (MH "Exercise+") OR (MH "Therapeutic Exercise") OR (MH "Group Exercise")
S13: (MH “Physical activity ”)
S14: Fit$
S15: Walk$
S16: Yoga
S17: Swim$
S18: S7 or S8 or S9 or S10 or S11 or S12 or S13 or S14 or S15 or S16 or S17
S19: S6 and S18
S20: (MH "Randomized Controlled Trials") OR (MH "Clinical Trials") OR (MH "Intervention Trials") OR (MH "Nonrandomized Trials")
S21: (MH "Experimental Studies") OR "intervention"
S22: S20 or S21
S23: S19 and S22

PsycINFO

S1: prenatal care or antepartum period
S2: prenatal
S3: pregnan$
S4: antenatal
S5: gestation
S6: postnatal period
S7: postpartum
S8: S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7
S9: diet
S10: nutrition
S11: nutrients
S12: physical activity or exercise
S13: exercise intensity
S14: swimming
S15: running
S16: yoga
S17: walking
S18: S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17
S19: S8 and S18
S20: trial
S21: intervention
S22: S20 or S21
S23: S19 and S22

Appendix D Systematic review data extraction form

General Study Details	
ID Number	
Title	
Author(s)	
Year	
Journal	

Study Description	
Study design	
Setting	
Target population Selection criteria	
Participants	
Intervention description	
Duration of intervention and timing of assessments	

Assessment	
Outcome variables of interest	
Assessment methods	
Baseline analysis	
Outcome analysis	

Results
Results from baseline analysis
All results for outcomes of interest
Summary of findings

Appendix D

Risk of Bias		
Item	**Comments**	**Score**
Study design		
Randomisation		
Blinding		
Intervention fidelity		
Attrition		
Sample size		
Outcome measures		
Statistical analysis		
Handling of confounding		
Intention to treat analysis		
Total		

Appendix E Systematic review quality assessment

Item	Risk of bias		
	Low (+1)	Medium (0)	High (-1)
Study design	Randomised controlled trial, including cluster randomised.	Quasi-experimental studies. Specifically, non-randomised controlled trials.	Observational studies, or intervention studies without an appropriate comparison. (Exclude from review)
Randomisation	Evidence that participants were successfully randomised. There should be no significant differences between groups at baseline.	Randomisation methods were used, but there are still differences between groups at baseline OR differences not analysed at baseline.	Participants were not randomised.
Blinding	Participants and analysts were blinded to treatment condition.	Participants were not blinded to treatment condition, but analysis of results was blinded.	Sufficient blinding methods were not employed.
Intervention fidelity	The intervention was delivered in a way that was not variable eg. Computer-generated.	The intervention was probably delivered consistently. Eg. The same person delivering a lesson to multiple groups.	The intervention was likely have been delivered differently across the trial. Eg. Asking midwives to provide information without providing further training.
Attrition	Loss to follow up of less than 10% AND similar loss in all groups.	Higher loss to follow up than expected (10%-30%). Similar loss between groups.	High dropout rate (>30%) and/or significant difference in follow up between groups.
Sample size	Power calculation is reported, and sample size meets requirements to detect change in diet or physical activity outcome.	Power calculation is not reported, but text states that recruitment was based on a power calculation OR sample size is very large (>1000).	No power calculation, unclear whether sample size is adequate OR powered for measure other than diet or physical activity behaviour.
Outcome measures	Reliable, validated measures that do not rely only on self-report.	Measures are validated and appropriate, but rely on self-reported data.	Unreliable methods including questionnaires that have not been piloted or validated, and methods that increase the likelihood of socially acceptable responses.
Statistical analysis	Statistical tests used are rigorous and appropriate for the data set. (Regression modelling, ANOVA, etc).	Statistical methods are effective, but not as rigorous as they could be.	Statistical methods are limited, and only report descriptive stats OR tests used are not appropriate for the dataset.
Handling of confounding	The analysis adjusted for all relevant confounding factors, or this was unnecessary because there were no differences between groups at baseline.	The model adjusts for most relevant confounders.	The model does not sufficiently adjust for relevant confounders.
Intention to Treat analysis	Intention to treat analysis was described and performed appropriately OR not necessary due to very low attrition.	Authors state that ITT was used, but methods or findings are insufficiently reported.	Only per-protocol analysis was performed when ITT would have been appropriate.

Appendix F Interview invitation letter

Supporting women to have healthy lifestyles during and after pregnancy

Dear [name],

We would like to hear about your experience in the SPRING study, and about the support you received from the research team while you were pregnant. We are also interested in how we can help women to have healthy lifestyles when they are pregnant and after they have given birth.

To do this, we would like to interview you about your pregnancy and how you are doing now that you have had your baby. We enclose an information sheet explaining what I want to discuss with you and how the interview will be run.

If you are happy to take part, please email a member of our team at tr@mrc.soton.ac.uk or phone 02380 764020.

We look forward to hearing from you.

Yours sincerely,

Taylor Rose
(on behalf of the SPRING team)

Appendix G Interview information sheet

Supporting women to have healthy lifestyles during and after pregnancy

Interview information sheet

Introduction

You have taken part in our SPRING study, which is investigating the benefits of vitamin D supplementation and additional nurse support during pregnancy. We would like to understand more about women's health and lifestyles during pregnancy, and how we can support them to have healthier pregnancies. We are therefore inviting you to be interviewed by one of our research team.

What does the interview involve?

You will be invited to discuss your pregnancy in an open and relaxed way with a trained interviewer from the SPRING team. We will arrange a convenient time to interview you at your home or in a place of your choosing. The interview should take no more than one hour, but may be shorter or longer depending on how much you would like to say. With your permission, the interview will be audio-recorded. What you say during the interview will be typed up from the recording and your name will be removed from the document so you will not be identified. The recording will then be destroyed.

What are the benefits of taking part?

You will be helping us to understand the health and lifestyles of women who are pregnant and about your experiences with the research nurses in SPRING. We will use this information to develop a new way of supporting women in the future to improve their health while they are pregnant and maintain this after they have given birth.

What if I would prefer not to take part?

You can decide whether or not to take part. If you do decide to take part, you are still free to withdraw from the study at any time and without giving a reason. This will not affect the care you receive.

Appendix H Interview discussion guide

Introduction

Hello, I'm *[name]* from the SPRING research team & I'll be interviewing you today. Before we get started, I'd just like to run through a few things with you. You took part in the SPRING study, which is investigating whether vitamin D during pregnancy improves the bone health of babies. You also got some extra support from the research nurses and I'd like to ask you about your health during pregnancy and how that has changed since you finished SPRING. The purpose of this interview is to understand more how to support women to have healthy lifestyles during pregnancy and to maintain this once they have given birth. The interview should take no longer than one hour.

You are free to end the interview at any time. We would like to audio-record these interviews, and these will be typed up, read by us in the research team and your name removed from the written version.

Are you happy for this conversation to be recorded?

*[Ensure that the participant is happy to continue and ask them to complete consent form – ensure it is **INITIALED**) Ask if they would like a copy.]*

General health in pregnancy

- What does it mean to you to have a healthy pregnancy? What factors are important?
- When you were pregnant, how did your health behaviours change?
- How important do you think it is to eat a healthy diet during pregnancy?
- How important do you think it is to exercise when you are pregnant?

Experience with HCS support during pregnancy

- What kinds of things did you talk to the research nurses about at your appointments?
- What goals did you set with them?
- What were your reasons for setting that goal?
- How important was it to you to reach the goals you set?
- What factors in your life supported you to reach your goals? What factors made it difficult?
- How did your conversations with the nurses affect your health behaviours?
- What do you remember about the 26-week phone call?
- What else do you think could have helped you reach your goals or have a healthier pregnancy?

Now that you have had your baby

- How have your health behaviours changed since you gave birth?
- What goals did you set for yourself post-pregnancy?
- How is it going with those goals now?
- What is helping, what is making it difficult?

- What do you remember about the 1-month follow-up appointment where the nurse came to your house?
- What kinds of things do you think would be helpful to keep reaching your goals now that you don't have any more contact with the research nurses?

Looking forward

- Now that your involvement with SPRING has ended, how do you feel about maintaining a healthy lifestyle moving forward?
- What kinds of things will you do to keep (eating healthfully/ exercising/ not smoking…)?
- What things do you think might help you to do that?
- What things to you think might make it difficult? How will you overcome those barriers?
- What other support do you think would be helpful?

Appendix I Focus group information sheet

MUMS' AND DADS' FOCUS GROUPS: HEALTH AND WELLBEING IN PREGNANCY

PARTICIPANT INFORMATION SHEET

Introduction

We would like to invite you to take part in a focus group on [date] when you are scheduled to attend [name of class]. We are interested in understanding more about the factors that influence women's health and lifestyle during pregnancy, and about their partners' experiences and involvement during and beyond pregnancy. Therefore, we will be running two focus groups during the lunch break; one with pregnant women and the other with their partners.

What do the focus groups involve?

You will be invited to discuss your pregnancy in an open and relaxed way over lunch with other parents who are taking the class. The focus groups will be facilitated by a trained interviewer from our research team in a confidential environment. The mums' focus group will talk about pregnancy experiences, lifestyle, and sources of support. The dads' focus group will talk about experiences of becoming a father, their own lifestyle, and sources of support. The focus group will be audio-recorded and what you say will be typed up from the recording. Names and identifying information will be removed from the document so you will not be identified, and the recording will then be destroyed.

Who can take part in the focus groups?

We would like to hear from everyone who is willing to take part in our focus groups. All pregnant women taking part in the class are welcome to attend the mums' focus group, regardless of whether your partner is attending. We would also encourage all partners attending the class to take part in the dads' focus group. Participation does not depend on whether or not you are currently in a relationship with the mum, and is not limited to biological fathers.

What are the benefits to taking part?

You will be helping us to understand the health and lifestyles of pregnant women, their partners and their families. We will use this information to develop new ways of supporting women in the future to improve their health while they are pregnant, and of similarly supporting fathers with their health and wellbeing. As the focus groups take place during the lunch break, we will provide lunch to all participants.

What if I/we would prefer not to take part?

You can decide whether or not to take part. If you do decide to take part, you are still free to withdraw or leave the group at any time without giving a reason. This will not affect any care or services you receive. Even if you decide to take part, you can choose not to answer any questions you do not want to answer. You do not have to give a reason for not wanting to answer a question.

Those who are willing to take part will be asked to join us during the lunch break.

If you have any questions about this, please contact Taylor Rose.
Phone: 023 8076 4020 (Mon-Thu only)
Email: tr@mrc.soton.ac.uk

Appendix J Focus group demographic questionnaire

MUMS' FOCUS GROUPS: HEALTH AND WELLBEING IN PREGNANCY

Please give the following background information.

What is your date of birth?

d	d	m	m	y	y

How would you describe your ethnic background? (e.g. White British) _____

What is your postcode? _____

How many children <18 years old live in your household with you? _____

What is your current profession? _____

How old were you when you left full-time education? _____

Which of these is your highest level of qualification?
Tick the box to indicate which one applies to you

- ☐ None
- ☐ GCSE grade D or lower/ NVQ1/ Foundation GNVQ/Scottish standard grade foundation/ School cert
- ☐ GCSE grade A,B,C/ RSA secretarial/ NVQ2/Intermediate GNVQ/Scottish standard grade general or credit/ Matric
- ☐ A levels/ AS Level/ City & Guilds/ EN(G)/ ONC/ NNEB/ BTech (day release)/ NVQ3/ Advanced GNVQ/ OND / HNC
- ☐ HND/ RGN/ NVQ4
- ☐ Degree/ NVQ5/PGCE/Postgraduate degree (e.g. Masters, PhD etc.)
- ☐ Other _____

Please tell us what qualifications.

Appendix K Focus group discussion guide

Introduction

Hello, thank you for agreeing to take part in this focus group. My name is Taylor, and I'll be running this focus group today. The reason I invited you here is that I am interested in the things that affect women's health and lifestyles during pregnancy. I would like to ask you all some questions about your pregnancies, your lifestyles and anything you think would be useful in supporting good health during pregnancy. This will take no longer than an hour.

Before we begin, I'd like to confirm that everyone is happy for the discussion to be audio-recorded. The recordings will only be heard by members of the research team, and when we type them up your names and any identifying information will be removed. You are free to withdraw or leave the group at any time without giving a reason, but it won't be possible to extract your comments to that point from the final transcript.

Everyone's contribution is valued, and it is helpful to keep conversations within the main group so I would ask you to keep confidential anything that is said during the focus group. We will use first names only. I'd encourage you to talk to each other about the questions I ask, not just to me, as this is a group discussion.

Introductory questions

- How many of you are in your first pregnancy?
- What made you decide to attend this class?

Sources of information/advice

- Aside from attending the class today, what resources do you use to find information or advice about your pregnancy?
    - Internet, books, apps, friends, family, health professionals…
- What kinds of things do you want to know? What do you ask about/ look up?
- How often do you seek advice about your lifestyle?

Health and lifestyle in pregnancy

- What kinds of things are important for a healthy pregnancy?
- What kinds of things do you think will affect your baby's health?
- How important is your diet when you're pregnant?
- How important is it to be physically active?
- How have your lifestyles changed since you fell pregnant?
- (If women talk about making changes):
    - What is your motivation to make those changes?
    - How do you think that might change after you give birth?
- What things (if any) have you found most difficult to change? What makes it difficult?

Appendix K

Sources of support

- What kinds of things support you to be healthy during your pregnancy?
    - Apps, antenatal groups, social support…
- Who in your life influences what you usually eat?
- How has your partner, or anyone else in your household, changed their lifestyle during your pregnancy?

Additional needs

- What other resources do you think would help you to have a healthy pregnancy?
- What community resources would be helpful?
- What could your midwife or other health professionals do to better support you?
- What features should be included in a pregnancy app or website that you think would be useful in supporting a healthy lifestyle?

Appendix L Dissemination of this work

Oral presentations

Complex adaptive systems in public health research
MRC Lifecourse Epidemiology Unit; unit seminar (2019)
Taylor Morris

Why do pregnant women respond differently to interventions designed to improve health behaviours?
Division of Health Psychology Annual Conference (2018)
Taylor Rose, Sofia Strommer, Christina Vogel, Nick Harvey, Cyrus Cooper, Hazel Inskip, Kath Woods-Townsend, Janis Baird, Mary Barker, Wendy Lawrence

Why do some pregnant women engage more than others with interventions to improve diet and increase physical activity ?
Southampton Medical and Health Research Conference (2018)
Taylor Rose, Sofia Strommer, Christina Vogel, Nick Harvey, Cyrus Cooper, Hazel Inskip, Kath Woods-Townsend, Janis Baird, Mary Barker, Wendy Lawrence

Complex adaptive systems in public health research
MRC Lifecourse Epidemiology Unit; team presentation (2018)
Taylor Rose

Why do some pregnant women engage more than others with interventions to improve diet and increase physical activity?
10th World Congress on Developmental Origins of Health and Disease (2017)
Taylor Rose, Sofia Strommer, Christina Vogel, Nick Harvey, Cyrus Cooper, Hazel Inskip, Kath Woods-Townsend, Janis Baird, Mary Barker, Wendy Lawrence

Poster presentations

Why do some pregnant women engage more than others with interventions to improve diet and increase physical activity ?
Southampton Festival of Doctoral Research (2018)
Taylor Rose, Sofia Strommer, Christina Vogel, Nick Harvey, Cyrus Cooper, Hazel Inskip, Kath Woods-Townsend, Janis Baird, Mary Barker, Wendy Lawrence

Why do some pregnant women engage more than others with interventions to improve diet and increase physical activity ?
10th World Congress on Developmental Origins of Health and Disease (2017)
Taylor Rose, Sofia Strommer, Christina Vogel, Nick Harvey, Cyrus Cooper, Hazel Inskip, Kath Woods-Townsend, Janis Baird, Mary Barker, Wendy Lawrence

Pregnant women's diet and physical activity behaviours, and their engagement with lifestyle support
MRC Lifecourse Epidemiology Unit; International Scientific Advisory Committee presentation (2017)
Taylor Rose, Sofia Strommer, Christina Vogel, Kathryn Woods-Townsend, Janis Baird, Mary Barker, Wendy Lawrence

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