Development of an app-based intervention to support healthy eating, physical activity and weight management in pregnancy.

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A thesis submitted for the degree of Doctor of Philosophy

Declaration

I, Alexandra Rhodes, confirm that the work presented in the thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Acknowledgements

First and foremost I should like to thank Dr Clare Llewellyn, my primary supervisor, not only for her generous support and guidance over the past five years, but also for encouraging me to undertake this PhD in the first instance. Had it not been for Clare planting the seed of a PhD in my mind, identifying the funding opportunity and handholding me through the application process, I might never have embarked on this hugely enjoyable and rewarding adventure. I have benefitted enormously from Clare's knowledge, wisdom and enthusiasm.

Huge thanks are also due to my other supervisors – Dr Helen Croker who patiently guided me through my first meandering 18 months, and Dr Andrea Smith who took over from Helen and was my sole support at UCL throughout Clare's maternity leave. Andrea's quick responses to my questions and queries and her meticulous feedback has helped me to navigate unfamiliar waters and to develop the new skills I needed for this PhD.

I have really enjoyed being part of the Energy Balance Group and am very grateful for the help and support I have received from past and present members of the team – in particular Dr Rana Conway, Dr Pippa Lally, Dr Anna Roberts and Gabby Heuchan - thank you.

This PhD would never have been had I not met Alison Baum, founder and then CEO of Best Beginnings, New Year's Eve 2009. Without her vision, energy, enthusiasm and commitment, the epic task of creating Baby Buddy would not have been achieved. I had the pleasure of supporting Best Beginnings in the development of Baby Buddy and many of the preceding resources which now sit within the app and was thrilled when Best Beginnings agreed to sponsor this PhD with Alison taking on the role of my external supervisor. Thank you Alison for this opportunity and your faith in my ability to deliver an intervention worthy of Baby Buddy.

Thank you also to the wider Baby Buddy team at Best Beginnings who helped to turn the ideas in this thesis into a functioning feature within Baby Buddy. Matt Black deserves a special thank you for his patience in helping me to understand the practical

aspects of creating an app feature and acting as the linchpin in the process of realising Baby Steps to Healthier Habits. I have thoroughly enjoyed working with all the Best Beginnings' team - Jenny McLeish, Nicola Cadbury, Jake Elgood-Field, Ruth Edmondson, Nilu Perera - and look forward to future collaborations.

Beyond Best Beginnings, thank you to my other funders – the Economic and Social Research Council, Surrey Heartlands Health and Care Partnership and the AIM Foundation. Thanks also must go to my PPIE group for their time and honesty in providing valuable input; to the team of experts who provided me with specialist knowledge on antenatal diet, eating behaviours, exercise and activity and to all my research participants who shared their experiences and opinions.. A special thank you to Professor Giles Yeo, Dr Chris van Tulleken and midwife Paula Lavandeira-Fernandez for so generously giving their time and permission to make the series of short films for the intervention.

Finally thank you to my long-suffering husband, David, for being a sounding board for my ideas, boosting my confidence during times of self-doubt and listening tirelessly to my pontifications on a subject of limited interest to him.

Abstract

Poor diet quality, physical inactivity and excessive weight gain in pregnancy are associated with adverse maternal and child health outcomes. Dietary and physical activity interventions can be effective in promoting positive behaviour change and healthy gestational weight gain (GWG). Whilst digital interventions have proven less effective than in-person interventions, their comparatively lower cost, scalability and greater accessibility make them an attractive proposition for healthcare providers. Baby Buddy, a free pregnancy and parenting app from UK charity Best Beginnings, is designed to support parents and improve health outcomes. Its use within the National Health Service makes it an ideal platform for delivering a new antenatal dietary and physical activity intervention. The aim of this thesis was to create a theory-based intervention within Baby Buddy to encourage and support expectant parents to develop healthier dietary and physical activity habits. Study 1 was a systematic review and meta-analysis of digital interventions targeting diet and/or physical activity in pregnancy. Meta-analyses showed lower GWG for interventions compared to controls, although the mean difference of was non-significant for both intention to treat studies (n= 3), (mean difference -0.28 kgs, 95% CI: -1.43, 0.87) and per protocol studies (n=4), (mean difference -0.65 kgs, 95% CI: -1.98, 0.67). An analysis of the behaviour change techniques used in the interventions informed the rudimentary intervention concept. Adhering to the principles of the Person-Based Approach to intervention development, three stages of qualitative research with target users (n= 83) guided the intervention design process (Studies 2, 3 & 4). Regular consultation with a Public Patient Involvement and Engagement group (n=18), Best Beginnings and other expert contributors (n=14) shaped the intervention design. The result, Baby Steps to Healthier Habits, was built and integrated into Baby Buddy with funding from the AIM Foundation. A service evaluation and feasibility study is planned.

Impact statement

The formative work presented in this thesis has culminated in Baby Steps to Healthier Habits (BaSHH), a digital intervention to encourage, support and guide expectant parents to develop healthier dietary and activity habits. There is increasing evidence that poor maternal diet and inactivity during pregnancy lead to adverse health outcomes not only during pregnancy and at birth, but throughout the life of the mother and child. Encouraging behaviour change during pregnancy – a time when motivation to improve health behaviours is often raised – could contribute towards better health outcomes during pregnancy and at birth, and also help to establish healthier dietary and physical activity habits for the long term. BaSHH has been designed to sit within Baby Buddy, an existing pregnancy and parenting app that is used within the UK's National Health Service (NHS). The app is free and available to every expectant and new parent in the UK and as such it offers an ideal platform for delivering a nationwide public health intervention. BaSHH will be launched in three UK regions in 2023 - Surrey Heartlands, North East London and Leeds - and a service evaluation and feasibility study will take place before the intervention is launched nationwide.

BaSHH was created using the Person-Based Approach (PBA) to health behaviour intervention development and the Behaviour Change Wheel. Detailed reporting of how these models and methods were applied to the different stages of the development process have been published in three peer-reviewed journals with the papers being cited 45 times (September 2023). The studies have also been presented at two international conferences (6th Annual Digital Health Conference - Behaviour Change for Health: New and emerging science and technologies, 2020; International Society of Behavioural Nutrition & Physical Activity Annual Meeting, Uppsala, Sweden, 2023), thus contributing to the knowledge base of digital health intervention development.

The project provided an opportunity for an MSc Health Psychology student, Arya Pimprikar, to undertake a dissertation project exploring the antenatal experiences of British Asian parents and investigating how to make the intervention relevant to and accessible for this community. This led to Arya securing permanent employment at Best Beginnings on graduating.

As the first collaborative project between UCL and Best Beginnings this project paved the way for the BRIGHT study, an MRC funded project to prevent overfeeding in bottle-fed babies. The knowledge and expertise in the PBA I had built up through my PhD allowed me to contribute to the BRIGHT study, in particular with regards to methodological issues.

As the COVID-19 pandemic forced a delay to my research plans, I took the opportunity to conduct a qualitative investigation into the experiences and needs of Baby Buddy users during the pandemic, exploring in particular its effect on their dietary and physical activity behaviours, as well as the role of digital pregnancy and parenting resources during the period in which UK citizens were being asked to stay at home (Rhodes, Kheireddine, & Smith, 2020). This study prompted a collaboration of three UK charities (Best Beginnings, Home-Start UK and the Parent-Infant Foundation) and formed the basis for a large, nationwide survey (n= 5474), Babies in Lockdown ("Babies in Lockdown," 2020). The Babies in Lockdown report was one of 11 influential works referenced in the Government's Early Years Healthy Development Review Report in 2021 ("The Best Start for Life A Vision for the 1,001 Critical Days The Early Years Healthy Development Review Report The Best Start for Life," 2021).

Publications and presentations

The following peer-reviewed publications and conference presentations have resulted from the work presented in this thesis:

Peer-reviewed publications:

Rhodes A., Smith A., Chadwick P., Croker H, Llewellyn C. Exclusively Digital Health Interventions Targeting Diet, Physical Activity, and Weight Gain in Pregnant Women: Systematic Review and Meta-Analysis. JMIR mHealth and uHealth 2020;8(7). https://mhealth.jmir.org/2020/7/e18255 DOI: 10.2196/18255 (Chapter 4)

Rhodes, A., Smith, A.D., Llewellyn, C.H. Investigating partner involvement in pregnancy and identifying barriers and facilitators to participating as a couple in a digital healthy eating and physical activity intervention. *BMC Pregnancy Childbirth* **21**, 450 (2021). https://doi.org/10.1186/s12884-021-03917-z (Chapter 5)

Rhodes A, Pimprikar A, Baum A, Smith A, Llewellyn C.H. Using the Person-Based Approach to Develop a Digital Intervention Targeting Diet and Physical Activity in Pregnancy: Development Study. JMIR Formative Research 2023;7:e44082. URL: https://formative.jmir.org/2023/1/e44082. DOI: 10.2196/44082 (Chapters 6, 7 & 9).

Conference presentations

Rhodes A., Smith A., Chadwick P., Croker H, Llewellyn C. Effectiveness and components of exclusively digital health interventions targeting diet, physical activity and weight gain in pregnant women: a systematic review and meta-analysis. 6th Annual Digital health Conference - Behaviour Change for Health: New and emerging science and technologies. 16-18 September 2020.

Rhodes A, Pimprikar A, Baum A, Smith A, Llewellyn C.H. Using the Person-Based Approach to Develop a Digital Intervention Targeting Diet and Physical Activity in Pregnancy: Development Study. International Society of Behavioural Nutrition & Physical Activity Annual Meeting, Uppsala, Sweden, 14-17 June 2023.

Additional publications

The following peer-reviewed publications and reports highlight other work I have been involved in throughout, but are not directly reported in this thesis:

Rhodes A., Kheireddine S., Smith A. Experiences, Attitudes, and Needs of Users of a Pregnancy and Parenting App (Baby Buddy) During the COVID-19 Pandemic: Mixed Methods Study JMIR mHealth and uHealth 2020;8(12): https://mhealth.jmir.org/2020/12/e23157 DOI: 10.2196/23157

Babies in Lockdown – Listening to parents to build back better, 2020. https://www.home-start.org.uk/Handlers/Download.ashx?IDMF=582bdd56-8950-452d-8b2e-52348a5788d9

This was a collaboration of three organisations – Best Beginnings, Home-Start UK and the Parent-Infant Foundation. It built on the Baby Buddy during COVID-19 study (Rhodes et al., 2020). The study reported on the experiences and attitudes of nearly 5500 expectant parents and parents of an under 2-year-old during the COVID-19 pandemic. My role was to develop the questionnaire for this project. I also contributed towards to analysis of the findings and the report writing. This report was referenced in the Government's Early Years Healthy Development Review Report in 2021 ("The Best Start for Life A Vision for the 1,001 Critical Days The Early Years Healthy Development Review Report The Best Start for Life," 2021).

Contributions to the work reported in this thesis

I designed and carried out the studies reported in this thesis, together with my supervisors Dr Clare Llewellyn, Dr Andrea Smith and Dr Helen Croker. My supervisor Alison Baum provided guidance on the practical aspects of developing this new feature for Baby Buddy and gave me access to her superb team at Best Beginnings. She also connected me with healthcare professionals who provided ad hoc input into the intervention development.

For Study 1 (Chapter 4) I prepared and registered the systematic review protocol, developed and refined the search strategy, and screened titles, abstracts and full-text articles for study selection (with a sub-sample reviewed for reliability by Dr Paul Chadwick). I carried out a risk of bias assessment, which was duplicated by Dr Andrea Smith. I carried out data extraction and data preparation for the meta-analyses, which was reviewed for reliability by Dr Helen Croker. Dr Paul Chadwick and I independently coded the behaviour change techniques within each intervention included in the review.

I designed Studies 2, 3 and 4 (Chapters 5, 6, 7 & 9). I determined the sample structures and recruitment strategies. I developed the topic guides and created the stimulus materials. I submitted the appropriate applications required for data protection and ethical approval, with support from Dr Helen Croker (Study 2) and Dr Clare Llewellyn and Dr Andrea Smith (Studies 3 and 4). I conducted all the interviews and moderated all the focus groups in Study 2 and the majority of the interviews in Studies 3 and 4, with support from MSc Health Psychology student Arya Pimprikar. For Study 2, I developed a coding framework with Dr Andrea Smith, who analysed a sub-sample of the interviews and focus groups. For Studies 3 and 4, I developed a Table of Changes, with input from Arya Pimprikar.

I prepared three manuscripts from the results of these four studies. The manuscript for Study 1 was submitted to and published in JMIR mHealth and uHealth. The manuscript for Study 2 was submitted to and published in BMC Pregnancy and Childbirth. The final manuscript, summarising the intervention development process (Studies 3 & 4), was submitted to and published in JMIR Formative Research. My supervisors provided

guidance on structuring the manuscripts and reviewed and edited each one prior to submission for publication. Anonymous peer reviewers provided constructive comments to improve the manuscripts prior to publication.

Between Studies 2 and 3, I identified and recruited participants for the PPIE group (n=10) from healthcare and grass-roots organisations supporting particular groups and/or aspects of perinatal health (n=8/10) and parents who had used the Baby Buddy app (n=2/10). I convened individual online meetings with PPIE participants. In addition I set up and held online meetings with a PPIE group of midwives (n=8). These sessions provided invaluable input into the research design, contributing in particular to the topic guide and stimulus materials for Study 3.

I identified and sought advice from experts within the fields of antenatal nutrition and physical activity (n=14). Online and in-person meetings and email exchanges with these individuals provided ad hoc input into the creation of the intervention content.

I designed all the bite-size messages (n=160), drafting initial versions, reviewing these with PPIE members, experts and research participants, and carrying out relevant edits. I also designed the additional content linked to the bite size messages, the onboarding script and the feedback messages (n=14). I worked closely with Baby Buddy's script writer, Dr Jenny McLeish, to ensure that all content was consistent with the Baby Buddy voice.

I prepared the brief for the app designers and, in conjunction with Matt Black at Best Beginnings, worked closely with the app designers to create a working design of the intervention to take to the app builders. I identified potential funding sources for the app build and submitted a successful grant application to the AIM Foundation.

I identified and recruited three individuals (Professor Giles Yeo, Dr Chris van Tulleken and Paula Lavandeira-Fernandez) who were willing to contribute short films to the intervention. With support from Best Beginnings' film maker, I briefed these individuals on the aims of the intervention and potential film content. I then worked with them to co-create scripts for the films and make the films.

In line with Best Beginnings' commitment to best practice, all intervention content was reviewed by the Editorial Board, which consists of representatives of key health organisations in the UK. I prepared all the intervention content for this process and made amendments to it based on the recommendations of the Editorial Board.

In the studies reported in this thesis (Chapters 4-7 & 9), contributing authors are referred to by their initials as follows:

Dr Clare Llewellyn: CL

Dr Andrea Smith: AS

Dr Helen Croker: HC

Dr Paul Chadwick: PC

Arya Pimprikar: AP

Alexandra Rhodes: AR

Table of Contents

Table of Tables

Tables of Figures

List of abbreviations

BaSHH: Baby Steps to Healthier Habits

BCTs: Behaviour Change Techniques

BCW: Behaviour Change Wheel

BMI: Body Mass Index

CCG: Clinical Commissioning Group

CI: Confidence Intervals

Cms: Centimetres

COM-B: Capability Motivation Opportunity Behaviour

FBM: Fogg Behaviour Model

Gestational diabetes: GDM

GWG: Gestational Weight Gain

HCPs: Healthcare Practitioners

IOM: Institute of Medicine

ITT: Intention to Treat

Kgs: Kilograms

LGA: Large for Gestational Age

MRC: Medical Research Council

NAM: National Academy of Medicine

NHS: National Health Service

NICE: National Institute for Health and Care Excellence

NNS: Non Nutritive Sweeteners

OR: Odds Ratio

PBA: Person-Based Approach

PP: Per Protocol

PPIE: Public and Patient Involvement and Engagement

RCT: Randomised Control Trial

RR: Relative Risk

SCT: Social Cognitive Theory

SD: Standard Deviation

TDF: Theoretical Domains Framework

UK: United Kingdom

UPFs: Ultra-Processed Foods

US: United States of America

WHO: World Health Organisation

Chapter 1 An overview of dietary and physical activity behaviours in pregnancy and gestational weight gain

1.1 Introduction

Maternal obesity and excessive gestational weight gain (GWG) are independently associated with adverse maternal and foetal health outcomes during pregnancy and birth (D'Souza, Horyn, Pavalagantharajah, Zaffar, & Jacob, 2019; Goldstein et al., 2017)**.** Poor maternal diet and excessive GWG also increase the risk of long-term weight-related illnesses in both mother and offspring (Gilmore, Klempel-Donchenko, & Redman, 2015). Currently levels of physical activity and dietary patterns in pregnancy are typically suboptimal and around half (51%) of all pregnant women in Western countries experience excessive GWG (Goldstein et al., 2018). However, pregnancy is a time when women are motivated to make positive lifestyle changes for the sake of their baby (Phelan, 2010). As such, it represents a window of opportunity to modify dietary and physical activity behaviours and support healthy GWG.

1.2 Current dietary, physical activity and GWG practices in pregnancy

1.2.1 Diet and physical activity guidelines for pregnancy

The World Health Organisation (WHO) recommends that pregnant women are counselled about healthy eating and physical activity during pregnancy to stay healthy and prevent excessive GWG (WHO, 2019). In many countries, including the United Kingdom (UK), dietary recommendations are similar to those for all adults, with the addition of food safety recommendations which are not discussed in this thesis. In the UK the National Institute for Health and Care Excellence (NICE) recommendations state that women should be advised to eat a healthy diet and be physically active during pregnancy and given practical and tailored information on how to achieve this. In the US the 2020-2025 Dietary Guidelines for Americans, recommendations specifically for pregnant women were included for the first time (U.S. Department of Agriculture and U.S. Department of Health and Human & Services., 2020). Whilst emphasising the importance of healthy dietary patterns, the guidelines focus heavily

on additional calorie requirements and weight management. Other countries advise pregnant women of their additional calorie requirement in pregnancy, although there is variation as to during which trimester and how many additional calories are needed (see Table 1-1).

Table 1-1: Additional calorie requirements in pregnancy

Country	**Additional daily calories recommended**
UK ("Healthy eating in pregnancy - Start for Life - NHS," 2021)	200 in the third trimester
Europe (European Food Safety Authority) ("Healthy weight gain during pregnancy | Eufic," 2023)	70 in the first trimester 260 in the second trimester 500 in the third trimester
US (U.S. Department of Agriculture and U.S. Department of Health and Human & Services., 2020)	340 in the second trimester 452 in the third trimester

It is unclear why such variation between recommendations for additional calorie requirements in pregnancy exists. Adding further uncertainty to their validity is the fact that the UK and European recommendations appear to apply to all women regardless of BMI, activity levels, GWG or any other factors which might affect calorie requirements. The US recommendations state that the additional calorie requirements are designed for women with a healthy pre-pregnancy weight and that women with overweight or obesity should ask their HCP for personalised advise on calorie intake. Women with pre-pregnancy underweight are not mentioned.

In Australia and Canada, dietary guidelines for pregnant women do not mention additional calorie requirement, although they reference the need for extra food. Rather these guidelines focus on healthy eating and how to achieve a healthy diet ("Healthy

eating when pregnant and breastfeeding - Canada's Food Guide," 2022; "Nutrition advice during pregnancy | Australian Government Department of Health and Aged Care," 2021).

Physical activity recommendations are more consistent across different countries and do not differ from those for the general adult population, with the typical guideline being that pregnant women should do 150 minutes of moderate intensity physical activity per week. Guidelines generally advise against sports that carry a risk of falls or collisions and many also include advice on indications for stopping exercise during pregnancy (Evenson et al., 2014).

1.2.2 An overview of GWG guidelines

Many countries monitor women's weight gain and provide guidelines for recommended GWG (Scott et al., 2014). In the USA the National Academy of Medicine (NAM) (previously known as the Institute of Medicine (IOM)) announced its first national guidelines for weight gain during pregnancy in 1990, with the recommended range of weight gain based on a woman's pre-pregnancy body mass index (BMI), and excessive GWG being defined as exceeding the upper boundary of the recommended range. The 1990 guidelines were revised in 2009 to reflect the growing prevalence of maternal obesity (see Table 1-2) (Rasmussen & Yaktine, 2009). These or similar guidelines have since been adopted by several other countries, but not the UK (Scott et al., 2014).

Table 1-2: National Academy of Medicine Guidelines for Weight Gain During Pregnancy

Pre-pregnancy weight status (kg/m^2)	**Recommended weight gain**	
Underweight (BMI < 18.5)	28-40 lbs	13-18 kgs
Normal weight (BMI 18.5-24.9)	25-35 lbs	11.5-16 kgs
Overweight (BMI 25-29.9)	15-25 lbs	7-11.5 kgs
Obese (BMI≥30)	11-20 lbs	5-9 kgs

Note. This table is recreated from Rasmussen & Yaktine, 2009.
BMI = Body mass index; lbs=Pounds; kgs= Kilograms.

The NAM guidelines were developed from the findings of observational studies, and as such should not be viewed as definitive boundaries of optimal GWG. Moreover whilst the NAM ranges of recommended weight gain vary according to 4 categories of pre-pregnancy BMI, there are no specific guidelines for sub-population groups such as adolescents, different ethnicities and women with higher grades of obesity (i.e. grade 2: BMI, 35.0-39.9 and grade 3: BMI $\geq$ 40). A 2019 study from the LifeCycle Project-Maternal Obesity and Childhood Outcomes Study Group meta-analysed individual participant data from 25 pooled cohort studies and 196, 670 participants to explore the relationship between GWG and adverse maternal and child health outcomes (Voerman et al., 2019). They identified broader ranges of optimal GWG for most BMI categories and included specific ranges according to obesity grade, as illustrated in Table 1-3. However, they concluded that the association between amount of GWG and adverse health outcomes was weak, thus questioning the value of GWG guidelines (see 1.4.1 for a more detailed discussion of the risks associated with excessive GWG).

Table 1-3: LifeCycle Project - Maternal Obesity and Childhood Outcomes Study Group: Optimal GWG ranges

Pre-pregnancy weight status (kg/m^2)	Optimal GWG Ranges
Underweight (BMI < 18.5)	14 - <16 kgs
Normal weight (BMI 18.5-24.9)	10 - <16 kgs
Overweight (BMI 25-29.9)	2 - <16 kgs
Obesity Grade 1 (BMI 30-34.9)	2 - <6 kgs
Obesity Grade 2 (BMI 35-39.9)	0 - <4 kgs (or weight loss)
Obesity Grade 3 (BMI ≥40)	0 - <6 kgs

It is unclear whether GWG guidelines contribute to better rates of healthy GWG. A systematic review and meta-analysis of studies (n=63) monitoring GWG using NAM guidelines reported that the mean GWG and the prevalence of GWG above guidelines have increased over the period between 2009 (when the guidelines were introduced) and 2018 (Martínez-Hortelano et al., 2020). Whilst there may be many economic and societal reasons for increasing rates of GWG, sub-optimal communication of GWG guidelines to pregnant women may also be a contributing factor. A systematic review (n= 17) of pregnant women's experiences of receiving guidance on recommended GWG reported that whilst 69% of women received advice, only 50% of advice was consistent with NAM guidelines (Whitaker, Becker, Healy, Wilcox, & Liu, 2021). These findings are supported by a narrative review of 54 articles which concluded that GWG guideline advice was often infrequent and inaccurate (Weeks, Liu, Ferraro, Deonandan, & Adamo, 2018). The provision of advice to pregnant women on GWG is discussed in more detail in section 1.2.3.

In the UK women are not routinely weighed during pregnancy and the use of GWG guidelines has never been standard practice, although some maternity services do refer to the NAM guidelines in their information resources. NICE recommendations

state that pregnant women be weighed at their first antenatal appointment (the 'booking appointment'), which should happen within the first 10 weeks of pregnancy, but thereafter only "if clinical management can be influenced or if nutrition is a concern" (Recommendation 2, National Institute for Healthcare and Excellence, 2010). Only those with a BMI > 30 kg/m^2 at their first appointment should be referred to a dietitian or healthcare professional for personalised advice on diet and activity. In line with this, the NHS UK website does not refer to GWG within its section on 'Keeping well in pregnancy'. Rather, weight gain is included under 'Common symptoms in pregnancy' where women are informed "*Weight gain in pregnancy varies greatly. Most pregnant women gain between 10kg and 12.5kg (22lb to 26lb), putting on most of the weight after week 20* (NHS, 2022b).

A recent randomised control trial (RCT) amongst pregnant women in England (n= 656) tested the use of GWG guidelines alongside regular antenatal weight monitoring by midwives and showed no effect of the intervention in preventing excessive GWG, compared to standard care (proportion with excessive GWG in intervention group 27.6% (81/305) versus control group 28.9% (90/311), (adjusted OR 0.84, 95% CI: 0.53,1.33) (Daley et al., 2019). The authors suggested that lack of effectiveness may have been due to poor intervention implementation and delivery, with midwives not always weighing women, setting target weights or encouraging women to weigh themselves. However, the lack of effectiveness of weighing as a stand-alone intervention on excessive GWG is consistent with a previous small systematic review (n=2 studies) (Fealy et al., 2017) and an Australian RCT of 396 pregnant women randomised to daily weighing or routine care (Arthur, Di Corleto, Ballard, & Kothari, 2020).

In its 2010 guidance, NICE concluded that there were several gaps in the understanding of optimum weight management in pregnancy, including how much weight should be gained during pregnancy ("Appendix D: Gaps in the evidence | Weight management before, during and after pregnancy | Guidance | NICE," 2010). In its 2017 update, NICE recommended research to investigate whether the NAM GWG guidelines are appropriate for the UK population (National Institute for Healthcare and Excellence, 2017).

In addition, the UK's use of a measure of BMI to determine whether women should receive further support during pregnancy has been questioned, given that BMI does not appear to be an accurate predictor of perinatal health outcomes (Chappell et al., 2013). Studies are currently underway to determine whether an alternative adiposity measure may be more appropriate in identifying women at risk of adverse pregnancy outcomes ("SHAPES | SHAPES | Newcastle University," 2022).

In March 2023 the WHO called for experts to develop global GWG standards and define optimal GWG ranges to reduce the risk of adverse maternal and infant outcomes (WHO, 2023).

1.2.3 Provision of advice and information on healthy eating, physical activity and weight gain in pregnancy

Experiences of women in the UK and elsewhere suggest that Healthcare Practitioners (HCPs) do not always adhere to guidelines instructing them to advise women about healthy eating, physical activity and weight gain in pregnancy (Grenier et al., 2021; Newson, Bould, Bronte, Sinclair, & Abayomi, 2022). Research indicates that antenatal HCPs often avoid these topics for various reasons including lack of time and resources, as well as lack of knowledge and confidence, particularly around communicating sensitively and avoiding weight stigma (De Vivo & Mills, 2019; Fieldwick, Smith, & Paterson, 2019; Flannery et al., 2019; Heslehurst et al., 2014). Absence of advice can lead pregnant women to conclude that diet, physical activity and GWG are not matters to be greatly concerned about (Weeks et al., 2018). However, when advice is received from HCPs, it is often criticised by pregnant women for being too general, not tailored to women's specific needs and not designed to help them change their behaviour (Arden, Duxbury, & Soltani, 2014). Additionally, the advice can be unclear and inconsistent, which can result in women simply ignoring it (Findley, Smith, Hesketh, & Keyworth, 2020).

Several studies have reported that in the absence of adequate dietary, physical activity and weight gain advice from HCPs, pregnant women turn to other sources of information, with the internet and social media being increasingly regarded as primary resources (Dalhaug & Haakstad, 2019; Sayakhot, & Carolan-Olah, 2016; Swift et al.,

2017). This is concerning given the lack of certainty over the accuracy of the information. UK researchers analysed 130 internet pages from a Google search on foods to eat and avoid during pregnancy and supplement use (Sidnell & Nestel, 2020). They reported that 80% of the pages contained at least some inaccurate information (compared to UK advice for pregnant women), with information from commercial organisations being significantly less accurate than information from not-for-profit organisations. Additionally the authors reported that 67% of the pages scored below the recommended score on the Flesch Readability Ease scale for public internet pages, meaning that the content was not necessarily easily accessible for users.

1.2.4 Pregnancy apps as a source of advice and information on healthy eating and physical activity

Pregnancy apps, widely used by women for foetal development information, are also seen as a 'go to' source of information about health and well-being in pregnancy (Lee & Moon, 2016). Similar to the internet though, the content of pregnancy apps is not always reliable. Three reviews of the nutritional advice and information in pregnancy apps, in the UK (n=29), Australia (n=51) and the Netherlands (n=57) have reported that most apps contain limited nutritional advice, some of which was inaccurate (defined as contrary to country guidelines) and potentially even harmful to pregnant women (Bland et al., 2020; Brown, Bucher, Collins, & Rollo, 2019; Faessen et al., 2022). Another review that identified and assessed the quality of the top 10 pregnancy apps in Australia found 2 of the top 10 apps contained incorrect GWG information and 2 provided misleading advice about the need to increase calorie intake and 'eat for two' (Musgrave, Kizirian, Homer, & Gordon, 2020). A further two reviews of pregnancy apps (n=27, n=54) assessed physical activity content and concluded that advice and information was often poor quality and insufficient to support women to achieve recommended levels of physical activity (Hayman et al., 2022; Tinius et al., 2021). Furthermore, one of the reviews noted that none of the apps reviewed (n=27) screened potential users for contraindications to physical activity during pregnancy and almost two thirds contained no reference to contraindications, thereby potentially putting pregnancies at risk (Hayman et al., 2022). Summarising these findings, a review of reviews (n=16) identified five main areas of concern with regards to commercially available pregnancy apps - information, transparency, credibility, privacy and security

- and concluded that with limited regulatory control, HCPs and users need to be cautious and evaluate the quality and safety of pregnancy apps prior to recommending or using them (Carrandi, Hayman, & Harrison, 2023).

The periods of 'lockdown' in 2020-2021 resulting from the COVID-19 pandemic confirmed the valuable role that apps and other digital resources can play in providing much-needed antenatal advice and information. These studies also highlighted the importance of a verified and trusted source of information and advice (Chatwin et al., 2021; Rhodes et al., 2020).

In summary, whilst guidelines on healthy eating, physical activity and weight gain in pregnancy exist is many countries, the quantity and quality of advice currently reaching women appears to be suboptimal. Digital resources, including pregnancy apps, are increasingly being used by pregnant women, but currently these resources cannot be trusted to contain accurate information that conforms to guidelines.

1.3 Prevalence and risk factors of maternal obesity, excessive GWG and poor dietary and physical activity behaviours in pregnancy

1.3.1 Maternal obesity and excessive GWG

Worldwide obesity rates are reported to have nearly tripled since 1975, with an estimated 40% of women living with overweight and a further 15% living with obesity (Vaamonde & Álvarez-Món, 2020). In line with these data, a recent meta-analysis of worldwide data reported 39% of women begin their pregnancy with either overweight or obesity, with prevalence higher in wealthier countries such as the UK (Martínez-Hortelano et al., 2020). Data drawn from the US indicate a continuation of this upward trajectory with an increase in pre-pregnancy obesity from 26.1% in 2016 to 29% in 2019 (Driscoll & Gregory, 2020). In the UK it is estimated that nearly half of women start pregnancy with overweight or obesity, with risk increasing with age and level of deprivation (PHE, 2019). Risk of maternal overweight and obesity also varies according to ethnicity and parity, with higher rates found amongst black women and multiparous women (PHE, 2019). The child-bearing years appear to be a time in which

many women gain weight, with pregnancy increasing the level of weight gain further. A study of over 2000 women found 18.1% of those who began their pregnancy with a healthy BMI had overweight or obesity at 12 months postpartum, and of those starting pregnancy with overweight 40% had obesity at 12 months post-partum (Siega-Riz et al., 2010). A meta-analysis of the changes in BMI of women between the ages of 15 and 35 reported a mean increase of 2.8 kg/m^2 (equivalent to 7.5 kg weight gain for a woman of 164 cms) in non-mothers, and nearly 3.5 kg/m^2 in mothers (Corder et al., 2020). However, whether increase in weight during the perinatal period is a function of pregnancy itself or behaviour change related to being a mother remains unclear.

Although absence of routine antenatal weight monitoring in the UK means data on rates of excessive GWG are sparse, in the US and Europe 51% of women are estimated to exceed NAM GWG guidelines (Goldstein et al., 2018). A study of over 2500 women in Southampton found that 48% of participants gained weight in excess of NAM guidelines, rising to 64% and 51% amongst women with overweight and obesity respectively (Hollis et al., 2017). A more recent study in Wales reported a 56% rate of excessive GWG, although the cohort was based on 275 women who had an elective Caesarean Section, which is known to be associated with excessive GWG (Garay, Sumption, Pearson, & John, 2021). Conversely, a study in Oxford reported a rate of excessive GWG of less than 30%, based on a sample of 656 women of all BMIs (Daley et al., 2019).

Women who start pregnancy with overweight or obesity are at particularly high risk of excessive GWG (Cheney, Berkemeier, Sim, Gordon, & Black, 2017). The evidence of other risk factors for excessive GWG is less clear. The association between excessive GWG and ethnicity and socio-demographic factors remains somewhat inconsistent. Women on low income are thought to be exposed to considerably more psychosocial and socio-ecological risk factors that can lead to poor dietary and activity behaviours and excessive GWG, such as depression, poor social support and poor access to healthy foods (Gaillard et al., 2013; Paul, Graham, & Olson, 2013). However recent research has challenged some of these conclusions and highlighted the complexity of the relationship between GWG and biopsychosocial factors (Garay et al., 2021). In their systematic review and meta-analysis of 70 studies (48 cohort 7 case–control and 15 cross-sectional) exploring the determinants of excessive GWG, Zhou et al identified

pre-pregnancy overweight (including obesity), younger age (≤ 30 years old), unemployment, primiparity, smoking, and being unmarried (including divorced) as risk factors, while pre-pregnancy underweight and inadequate antenatal care were protective factors for excessive GWG (Zhou, Peng, Yi, Tang, & You, 2022). Contrary to two earlier studies that reported low educational attainment to be associated with weight gain outside of the NAM guidelines (O'Brien, Alberdi, & McAuliffe, 2018; Samura et al., 2016), in this meta-analysis no association was found between educational attainment and excessive GWG. This variability in study findings highlights the complexity of identifying risk factors, with the interrelatedness of many of these risk factors making it particularly challenging to identify the primary predictors of excessive GWG.

1.3.2 Poor dietary behaviours during pregnancy

A recent systematic review of 18 studies across nine countries investigating dietary patterns in pregnancy concluded that adherence to dietary guidelines is low, with pregnant women typically not meeting the minimum requirements for vegetable and cereal intake, but exceeding fat intake. (Caut, Leach, & Steel, 2020). This review did not include the UK and to date the author is unaware of any UK study exploring pregnant women's adherence to dietary guidelines/The Eatwell Guide (NHS, 2022a). A UK study investigating the dietary quality of pregnant women living with obesity (n=140) reported sugar and protein consumption significantly in excess of recommended guidelines, and dietary fibre consumption significantly below recommended guidelines (Charnley, Newson, Weeks, & Abayomi, 2021). In Australia, a study that aligned the dietary patterns of pregnant women and their partners with the Australian Guide to Healthy Eating recommendations found very low proportions of participants meeting their five core food group intake recommendations (Wilkinson et al., 2022). For example, only 28% of women and 15% of men met their recommended vegetable intake recommendations and around a third of calorific intake came from non-core foods like biscuits, cakes, pies and processed meats. Interestingly this study reported that women were more likely to meet daily recommendations for most core food groups when their partners also met the recommendations.

At a more granular level, pregnant women in developed countries appear to have a deficiency of key micronutrients such as iron, folate and Vitamin D. (Blumfield, Hure, Macdonald-Wicks, Smith, & Collins, 2013). In the UK similar micronutrient deficiencies have been reported, along with inadequate iodine levels (Charnley et al., 2021). UK population data indicate that similar trends apply to all pregnant women of all BMIs (Rauber et al., 2019; Ruxton & Derbyshire, 2010).

Although women often make changes to their dietary behaviours during pregnancy, these can be negative as well as positive changes (Kebbe, Flanagan, Sparks, & Redman, 2021). The only consistently observed change is an overall increase in energy intake (Hillier & Olander, 2017). A Canadian study (n=110) comparing a sample of matched pregnant (n=55) and non-pregnant women (n=55) found that overall diet quality in the sample was low although pregnant participants did have a significantly higher quality diet but also higher energy intake. (Savard et al., 2020).

The complex mix of psychosocial, economic and environmental influences on dietary behaviour means that isolating key predictors of poor dietary behaviours in pregnancy is challenging. A study individual participant data (n=26,410) from 7 European cohorts, including 2 from the UK, reported higher maternal age, education, household income, and physical activity during pregnancy to be associated with a better dietary quality, as assessed by the Dietary Approaches to Stop Hypertension score. Conversely multiparity, smoking during pregnancy and pre-pregnancy obesity were found to be associated with poorer dietary quality (Aubert et al., 2022).

Dietary data from the general UK population give more insight into the potential risk factors for poor diet. An investigation into the dietary patterns of child-bearing-aged women (aged 18-49 years) in the UK reported low to medium adherence to a Mediterranean or ‘healthy’ diet, especially amongst those of white ethnicity, from a younger age group, from a lower socioeconomic background and who were less physically active (Khaled, Almilaji, Köppen, Hundley, & Tsofliou, 2019). The National Food Strategy, an independent review commissioned by the UK Government in 2021, reported that dietary patterns correlate with income and education, with those from lower socioeconomic groups eating less fruit and vegetables and slightly more sugar (“The Report - National Food Strategy,” 2021).This review also noted that as income

decreases, the likelihood of food insecurity rises, resulting in reduction in the quality, variety and desirability of diets, and for those experiencing greatest food insecurity, disrupted and reduced food consumption due to lack of money and resources.

Since the cost of living crisis in 2022, the UK has seen rising levels of food insecurity ("New data shows food insecurity major challenge to levelling up agenda | Food Foundation," 2022). In 2023, a report from First Steps Nutrition estimated 27% of households with children under 4 years old to be food insecure (First Steps Nutrition, 2023). The report noted that the Healthy Start allowance, an NHS scheme that that provides access to vegetables, fruit, milk, baby formula and vitamins for pregnant women and parents of babies under 4 years old for those on very low incomes, had not risen in line with inflation and was currently insufficient to cover the costs of formula feeding.

Cost is not the only factor underlying the association between dietary quality and socioeconomic group. Food availability in the UK differs between areas of high and low deprivation with the latter having less access to healthier foods and a greater prevalence of fast food outlets (Cummins & Macintyre, 2002; Public Health England, 2018). The combination of cost and food availability mean that achieving a healthy diet is considerably more challenging for those living in areas of deprivation and on low incomes.

1.3.3 Poor physical activity and sedentary behaviour during pregnancy

In the UK, around 20% of women of childbearing age are classified as inactive, meaning they do less than 30 minutes of moderate to vigorous activity per week (PHE, 2019). In pregnancy levels of physical activity typically decrease, both in pregnant women and their partners (Abbasi & van den Akker, 2015; Gropper, John, Sudeck, & Thiel, 2020). In their systematic review (n=44) of studies investigating levels of physical activity in pregnant populations worldwide , Silva-Jose et al (2022) reported that current levels are well below universal recommendations, which could mean significant risks to maternal physiological, mental, emotional health as well as child health (Silva-Jose, Sánchez-Polán, Barakat, Gil-Ares, & Refoyo, 2022). A systematic review (n=26) of sedentary behaviours in pregnancy reported that pregnant women spend over 50% of

their time in sedentary behaviours (Fazzi, Saunders, Linton, Norman, & Reynolds, 2017).

Fewer studies have explored the predictors of physical activity or sedentary behaviour during pregnancy. A Norwegian study (n=555) showed failure to meet recommended guidelines to be associated with ethnic minority background, multiparity, high body fat percentage, and perception of few physically active friends (Richardsen et al., 2016). A Finnish study (n=399) reported that the strongest predictors of maintaining physical activity during pregnancy were pre-pregnancy activity, higher education level and having an active partner (Leppänen et al., 2014).

In summary, dietary behaviours, physical activity and weight gain in many pregnant women are falling short of recommend levels for optimal health. However, there is lack of clarity around the risk factors associated with these sub-optimal behaviours and outcomes.

1.4 Risks associated with excessive GWG, poor dietary behaviours and inactivity in pregnancy

1.4.1 Risks associated with excessive GWG

Excessive GWG has been linked to greater risk of adverse maternal and infant health outcomes during pregnancy, at birth and throughout life as detailed below. The most recent individual participant data meta-analysis of nearly 200,000 participants from 25 pooled cohort studies showed excessive GWG, independent of pre-pregnancy BMI, to be associated with adverse health outcomes, defined as one or more of the following: preeclampsia, gestational hypertension, gestational diabetes (GDM), Caesarean delivery, preterm birth, and small or large size for gestational age at birth (Voerman et al., 2019). This association was weak, with a stronger association observed between pre-pregnancy BMI and adverse health outcomes.

Previous studies have reported pregnancy complications associated with excessive GWG to include GDM and hypertensive disorders (Hedderson, Gunderson, & Ferrara, 2010; Ruhstaller et al., 2016). At birth, excessive GWG has been shown to be

associated with macrosomia and large-for-gestational-age (LGA) babies (Adams et al., 2019; Ferraro et al., 2012; Tian et al., 2016), increasing the risk of shoulder dystocia and Caesarean section (Hill & Cohen, 2016; Rogozińska et al., 2019). Excessive GWG has also been associated with an increased risk of infant mortality. Whilst the correlation between maternal BMI and the risk of infant mortality is linear, a U-shape association between GWG and risk of infant mortality is an important reminder that whilst excessive GWG is problematic, so too is inadequate GWG (Bodnar et al., 2016).

Women who exceed GWG guidelines are more likely to be affected by postpartum weight retention, retaining an average of 4.45 kgs more at six months postpartum (Hollis et al., 2017) and 3 kgs more at 3 years postpartum (Nehring, Schmoll, Beyerlein, Hauner, & von Kries, 2011) compared to those adhering to GWG guidelines. Consequently, women who exceed GWG guidelines are more likely to start a subsequent pregnancies with overweight or obesity, instigating a cycle of weight gain throughout childbearing years, and exposing themselves and their infants to the risks of adverse health outcomes associated with maternal obesity (Gilmore et al., 2015). Indeed, women who transition from normal weight to overweight or obesity between pregnancies have been reported to have an increased risk of both still birth and neonatal mortality, with a dose-response relationship between BMI gain and risk of adverse outcome (Cnattingius & Villamor, 2016; Whiteman et al., 2011; Yu, Bodnar, Himes, Brooks, & Naimi, 2020). However, it should be noted that whilst any elevated risk is undesirable, the absolute risk of these adverse outcomes is low (UK 2020 data reports 3.33 still births per 1000 births and 1.53 neonatal mortality per 1000 live births) (Draper et al., 2022). Whether this weight gain is a function of postpartum weight retention or weight gain during the postpartum period is not clear. However, weight gain pre-pregnancy and inter-pregnancy is also associated with adverse health outcomes. A systematic review and meta-analysis (n=61) found pre-pregnancy and inter-pregnancy weight gain increased women's risk of GDM (OR 1.88, 95% CI:1.66, 2.14), hypertensive disorders (OR 1.46, 95% CI:1.12, 1.9), preeclampsia (OR 1.92, 95% CI:1.55, 2.37), and LGA (OR 1.36, 95% CI:1.25, 1.49) (Nagpal et al., 2022).

Excessive GWG is also associated with long term weight related health issues for the infant (Godfrey et al., 2017). Although pre-pregnancy maternal weight is a more significant risk factor, studies have consistently shown that excessive GWG is linked

to an increased risk of childhood overweight and obesity (Ohlendorf, Robinson, & Garnier-Villarreal, 2019; Voerman et al., 2019). Animal studies have helped explain this association by showing that diet-induced maternal obesity causes obesity, diabetes, fatty liver, hypertension and behavioural changes in offspring (Patel, Pasupathy, & Poston, 2015; Rhee, Phelan, & McCaffery, 2012). By increasing the risk of childhood overweight and obesity, excessive GWG predisposes offspring to a range of metabolic related illnesses and cancers (Fraser et al., 2010; Glastras, Chen, Pollock, & Saad, 2018; Simmen & Simmen, 2011).

Whilst these associations are widely reported, evidence for a causal link between excessive GWG and adverse health outcomes during pregnancy and at birth remains inconclusive. As shown by a meta-analysis of 49 RCTs, interventions which successfully reduce the risk of excessive GWG do not always lead to improved maternal and foetal health outcomes (Muktabhant, Lawrie, Lumbiganon, & Laopaiboon, 2015). Although Muktabhant et al found evidence of 20% reduced risk of excessive GWG in intervention groups compared to control groups (average RR 0.80, 95% CI:0.73, 0.87), there was no significant difference between the groups with regard to pre-eclampsia, Caesarean delivery, preterm birth or poor neonatal outcomes. In contrast, a recent meta-analysis of 117 RCTs reported antenatal dietary and physical activity interventions to be associated with reduced risk of GDM (OR 0.79, 95% CI: 0.70, 0.89), and of total adverse maternal outcomes (OR 0.89, 95% CI: 0.84, 0.94) compared to standard care (Teede et al., 2022).

Clearly the complex aetiology of GWG and these adverse maternal and foetal health conditions presents a challenge in pin-pointing the risks and determining the protective benefits of healthy GWG. A further complication is that the definition of excessive GWG is based on BMI, which may be suboptimal when used to predict health risks as it cannot disaggregate total body fat from lean mass (Khanna, Peltzer, Kahar, & Parmar, 2022). This means that someone with a higher-than-average level of muscle mass and a high percentage of fat-free mass may be misclassified as having overweight or obesity, and vice-versa. Waist circumference and waist to hip ratio may be preferrable measures of adiposity for health risks as they capture fat distribution. Two systematic reviews and meta-analyses (n=70 and n=34 studies respectively) of observational studies reported associations between higher adiposity in pregnancy and a range of

poorer maternal health outcomes, including GDM, hypertensive disorder, Caesarean or instrumental delivery, and poorer infant health outcomes such as LGA, pre-term delivery, neonatal morbidity and mortality (Heslehurst et al., 2022; Nguyen et al., 2022). A further meta-analysis using individual participant data is underway which will allow for a direct comparison of BMI with other measures of adiposity or a combined adiposity and BMI measure in the same population (Boath, Vale, Hayes, Allotey, & Heslehurst, 2023).

1.4.2 Risks associated with poor dietary behaviours in pregnancy

This section focuses on the effect of maternal dietary patterns and intake of some food groups on pregnancy outcomes. The adverse effects on foetal development of certain micronutrient deficiencies such as folic acid, iodine, iron and B complex vitamins are well documented and not discussed in this thesis (Mousa, Naqash, & Lim, 2019).

Research has consistently shown that it is not simply GWG that effects maternal and foetal health, but quality of maternal diet in pregnancy, although studies with human populations are largely observational, meaning that no causal link can be concluded. Independent of energy intake, diet quality has been associated with hypertension disorders including preeclampsia and higher birthweight, increased risk of LGA babies and infant adiposity (Perry, Stephanou, & Rayman, 2022; Shapiro et al., 2016; Zhu et al., 2019). Observational studies focussing on particular dietary patterns point to the protective effects of a healthy diet (Chen et al., 2016; Hajianfar, Esmaillzadeh, Feizi, Shahshahan, & Azadbakht, 2018). In particular, there is increasing evidence of a diet comprising a high intake of fruit, vegetables, whole grain cereals, legumes, fish and nuts and a low intake of dairy products and red meat (often referred to as the Mediterranean diet) being associated with better maternal and foetal health outcomes when compared to a traditional Western diet (high in meat, meat products, sugar and animal fats) (Zaragoza-Martí et al., 2022). These include reduced risk of GDM and reduced risk of cardiometabolic and congenital defects in offspring (Amati, Hassounah, & Swaka, 2019; Assaf-Balut et al., 2018). A multicentred cohort study in the US (n=7798) reported a 21% lower risk of any adverse pregnancy outcome (defined as gestational hypertension, preeclampsia or eclampsia, GDM, preterm birth, small-for-gestational-age infant or stillbirth) when comparing those with high versus low

adherence to the Mediterranean diet (OR 0.79, 95% CI: 0.68, 0.92), with evidence of a dose-response association (Makarem et al., 2022). The authors found no differences according to race, ethnicity or pre-pregnancy BMI, strengthening the evidence in favour of diet quality as an important underlying mechanism in the association between excessive GWG and adverse maternal and foetal health outcomes.

Drilling down to the aspects of the Western diet that make it less favourable to positive pregnancy outcomes compared to the Mediterranean diet, sugar and non-nutritive sweeteners (NSS) and ultra-processed foods (UPFs) have been identified as problematic. The evidence for each is discussed below.

- **Free sugars and non-nutritive sweeteners**

High free sugar consumption in pregnancy is associated with excessive GWG, GDM and preeclampsia (Casas, Barquero, & Estruch, 2020). The effects of high free sugar consumption in pregnancy appear to extend to off-spring, with growing evidence of its impact neonatal and childhood metabolism, taste perception and obesity risk (Goran, Plows, & Ventura, 2019; Ojha, Fainberg, Sebert, Budge, & Symonds, 2015). A US study of pregnant adolescents (n=121) showed sugar intake, rather than GWG, to predict foetal adiposity (Whisner et al., 2015). However, replacement of free sugars by non-caloric or metabolically less available substitutes is not a 'fix-all' solution to address these health complications. In the general population, there is epidemiological evidence to suggest a link between consumption of NNS and greater risk of obesity, metabolic syndrome and type 2 diabetes, although there is less clarity around the mechanisms which might explain this (Conz, Salmona, & Diomede, 2023; Pepino, 2015). In 2023, based on a systematic review and meta-analysis (n=283) highlighting potential associated health risks of consuming NNS, the WHO issued new guidelines advising against the use of NNS for weight control (Rios-Leyvraz & Montez, 2022). This study showed consumption of NNS in pregnancy to be associated with a 25% increase in risk of pre-term birth (OR 1.25, 95% CI: 1.07, 1.46), although the evidence for this was based on only three, relatively small cohort studies (total n=6381). A small systematic review of six prospective cohort studies suggested that the consumption of NNS during pregnancy may increase off-spring weight trajectories (Li et al., 2022). However, this finding was similarly based on a meta-analysis of only three studies, two

of which were rated as having a moderate risk of bias due to missing data. As the authors noted, further studies are needed to confirm this relationship. Like all nutritional epidemiology, understanding the health effects of NNS is problematic due to numerous confounding factors (see page 41). For NNS, a further complication arises from the different reasons underlying their consumption. For example NNS consumption may be driven by weight management in people living with overweight or obesity and the negative health effects could be related to weight rather than NNS consumption. Others may choose NNS in some foods to give themselves permission to consume other high sugar foods, which may be contributing to detrimental health effects.

- **UPFs**

UPFs are typically defined as foods produced in a factory by processing, and containing additives such as thickeners, colours, emulsifiers, sweeteners (Monteiro, Cannon, Lawrence, Laura Da Costa Louzada, & Machado, 2019). Based on data from the UK National Diet and Nutrition Survey (2008–2014), an average of around 57% of an adult's daily energy intake comes from UPFs (Rauber et al., 2019). This study also noted that increased consumption of UPFs had a direct and significant impact on average consumption of free sugars (9.9% to 15.4% of total energy from the first to the last quintile of UPF consumption). In the general population observational studies have associated consumption of UPFs with greater risk of overweight and obesity (Crimarco, Landry, & Gardner, 2022; de Araújo et al., 2021). Whilst a logical assumption might be that the adverse health effects of UPF consumption is a consequence of poorer quality of diet in general, in their review of prospective cohort studies (n=37), Dicken and Batterham (2022) showed the association between UPFs and adverse health outcomes remained after adjustment for diet quality/pattern, suggesting that aspects of ultra-processing may be important factors that impact health (Dicken & Batterham, 2022). In pregnant women, the consumption of UPFs has been shown to be associated with excessive GWG (Oliveira et al., 2022). A meta-analysis (n=61) has also linked high consumption of UPFs with GDM (OR 1.48, 95% CI: 1.17, 1.87) and preeclampsia (OR 1.28, 95% CI: 1.15, 1.42) (Paula, Patriota, Gonçalves, & Pizato, 2022). Whether this is due to higher free sugar consumption (in line with Rauber et al's findings), a function of another attribute of UPFs (e.g. aspects of the processing) or other population characteristics of UPF consumption is unclear for now.

Understanding the link between poor dietary behaviours and maternal and child health outcomes is challenging. The data come primarily from observational studies, meaning that whilst associations can be detected, they are vulnerable to confounding factors and no conclusions can be drawn with respect to causation. RCTs where different dietary patterns are allocated to different groups of pregnant women are achievable, although these are typically time-consuming and resource-intensive. Moreover, drop-out rates tend to be high and strict adherence to dietary patterns cannot be guaranteed (Al Wattar et al., 2019; Broekhuizen et al., 2018).

A further challenge arises from the limitations of the dietary assessment tools used in most of these studies. Tools such as the Food Frequency Questionnaire and 24-hour Dietary Recall rely on participants accurately recalling what they have eaten. Also, in the case of the latter, there is no guarantee that the 24-hour period recorded is typical of that individual's diet (Dao et al., 2019). However, animal studies, where diets can be manipulated, provide evidence that the link between poor maternal diet and offspring adiposity is causal. Offspring of rats fed a 'junk food' diet (energy dense foods high in sugar, fat and salt) in pregnancy have been shown to develop a preference for fatty, sugary, salty foods (Bayol, Farrington, & Stickland, 2007), leading to increased adiposity and earlier onset of conditions related to diabetes (Bayol, Simbi, Bertrand, & Stickland, 2008). Human studies have suggested that tastes begin to develop in-utero and foetal experiences of flavour can affect taste preferences in babies even months after they are born (Mennella, Jagnow, & Beauchamp, 2001). It may be possible that via these mechanisms, mothers who consume high levels of UPFs could be predisposing their children to a preference for an unhealthy diet.

Poor maternal diet in pregnancy has also been shown to be associated with maternal mental health issues both in pregnancy and postpartum (Barker, Kirkham, Ng, & Jensen, 2013; Baskin, Hill, Jacka, O'Neil, & Skouteris, 2017). Once again, the potential impact of confounding factors should not be ignored when considering these findings. Whilst studies typically adjust for covariates such as socioeconomic status, other known confounders such as work stress and social support may not be accounted for. However, these findings are consistent with studies on general populations which show an association between dietary patterns, consumption of specific foods including UPFs and sugar sweetened beverages and depressive symptoms (Huang, Liu, Suzuki, Ma,

& Liu, 2019; Lane et al., 2022). Since most of these studies rely on cross-sectional data, no conclusions can be drawn over causation. It may be that experiencing depressive symptoms leads to consumption of high sugar and high fat foods rather than (or even in addition to) vice-versa. However, a prospective cohort study (n= 10,380) examining the link between sugar intake from sweet food and beverages and common mental disorder and depression was able rule out reverse causation - that poor mental wellbeing leads to increased sugar consumption (Knüppel, Shipley, Llewellyn, & Brunner, 2017). The SMILES trial (n=67) tested a 12 week dietary intervention against a social support control for the treatment of depression (Jacka et al., 2017). Intervention participants (n=33) were given seven dietary support sessions and provided with food hampers comprising portions, recipe ideas and meal plans for a Mediterranean-style diet. Of those with complete data at 12 weeks, the dietary intervention group (n=31) showed a significantly greater improvement in depression symptoms compared to the control group (n=34), with 32.3% (n=10) of intervention participants achieving remission from depressive symptoms compared to 8% (n=2) of control participants. It should be noted that criticisms have been made about the recruitment methods and sample size in this study (Molendijk, Fried, & Van Der Does, 2018).

1.4.3 Risks associated with physical inactivity and sedentary behaviour in pregnancy

Rather than identifying risks associated with inadequate levels of physical activity, most of the literature focuses on the benefits and safety of physical activity during pregnancy (Cilar Budler & Budler, 2022; Cooper & Yang, 2023). A systematic review and meta-analysis of RCTs (n=30) and cohort studies (n=51) exploring the effect of leisure time physical activity in pregnancy focussed on three maternal outcomes, GDM, preeclampsia and GWG, and three child outcomes, preterm birth, birthweight and fetal growth (da Silva, Ricardo, Evenson, & Hallal, 2017). The meta-analysis of RCTs showed participation in leisure time physical activity to be associated with lower GWG (RR 0.67; 95 % CI:0.49, 0.92), lower likelihood of GDM (RR 0.67, 95 % CI:0.49, 0.92), and lower likelihood of delivering an LGA infant (RR 0.51, 95 % CI:0.30, 0.87). Cohort studies showed that participation in leisure time physical activity was associated with lower GWG, lower likelihood of GDM, and lower risk of preterm delivery. Other

systematic reviews support the association between being active in pregnancy and reduced the risk of developing GDM (Ming et al., 2018; Russo, Nobles, Ertel, Chasan-Taber, & Whitcomb, 2015). Regular physical activity in pregnancy is also associated with greater psychological wellbeing during pregnancy (Da Costa, Rippen, Dritsa, & Ring, 2003), better labour and delivery outcomes (Rodríguez-Blanque, Sánchez-García, Sánchez-López, & Aguilar-Cordero, 2019; Szumilewicz et al., 2013), including reduced risk of Caesarean section (Baena-García et al., 2020) and reduced risk of postpartum depression (Nakamura et al., 2019).

Sedentary behaviour, independent of physical activity appears to have a negative impact on health, cardiometabolic health in particular (Henson et al., 2013; van der Ploeg & Hillsdon, 2017). In pregnancy, the effects of sedentary behaviour are less well established. A systematic review of primarily cohort and cross-sectional studies (n=26) found little consistent evidence of associations between sedentary behaviours and maternal and infant health outcomes although women whose babies were diagnosed with macrosomia (weighing 4 kilos and above) had higher levels of sedentary behaviour in pregnancy than those whose babies weighed less than 4 kilos (Fazzi, Saunders, Linton, Norman, & Reynolds, 2017). Subsequent studies have found no association between sedentary behaviour and birth size, but have reported associations between high sedentary behaviour and shorter gestations, inhibited fetal growth, pregnancy-induced hypertension and/or preeclampsia and increased loss of blood during delivery/postpartum (Badon, Littman, Chan, Williams, & Enquobahrie, 2018; Jones, Catov, Jeyabalan, Whitaker, & Barone Gibbs, 2021; Meander et al., 2021). These inconsistencies can be partially explained by considerable heterogeneity in the measurement and definition of sedentary behaviour. Whereas some studies use objective measures such as accelerometers and heart rate monitors, others use subjected measures of time sitting or watching TV.

Similarly, studies vary in the way in which they measure physical activity. Whereas some use self-reported measures, using questionnaires such as the Pregnancy Physical Activity Questionnaire, which rely on accurate self-reporting and good recall, others use accelerometers or smart monitors, a drawback of which is that they are costly and they cannot be used in water so do not record swimming or other water-based activities and are sub-optimal for capturing strength-based physical activities

(Chasan-taber et al., 2004; Mendinueta et al., 2020). Moreover, wearing such monitors can results in participants changing their behaviour, known as the Hawthorne effect (Adair, 1984). Studies also vary in terms of when during pregnancy and for how long they measure physical activity. This is particular problematic given that levels of physical activity are known to drop off during the third trimester of pregnancy. Moreover, as with all observational studies, there is a risk of confounding factors, especially dietary behaviours which are correlated with physical activity and hard to control for. Whilst there is a plethora of evidence supporting the benefits of physical activity to overall health and increasing insight into the mechanisms involved, the evidence for the effects of physical activity in pregnancy on maternal and child outcomes needs to be assessed in the light of the limitations of these studies (Posadzki et al., 2020; Ruegsegger & Booth, 2018).

In summary, there is increasing but inconclusive evidence of poor dietary and physical activity behaviours in pregnancy being associated with a greater risk of adverse maternal and child health outcomes. Whilst it is challenging to draw conclusions on the strength of the links between diet quality and maternal child health, strongest evidence suggests that a diet lower in free sugars is beneficial for the metabolic health of pregnant women and a diet high in vegetables, fruit and pulses, but low in red and processed meat is protective against adverse pregnancy outcomes. Similarly, the strength of the links between physical activity in pregnancy and maternal and child health outcomes is somewhat unclear, although there is strong evidence to substantiate that physical activity is both safe in pregnancy and beneficial to overall health and well-being. Given the limitations of observational studies, this area would benefit from more RCT data.

1.5 Motivations and barriers to healthy eating and physical activity in pregnancy

Women's motivation to improve their health behaviours in pregnancy has been reported widely, with pregnancy often being considered to be a time of opportunity or 'teachable moment' when heightened motivation can lead to behaviour change (Phelan, 2010; Vanstone, Kandasamy, Giacomini, DeJean, & McDonald, 2017). Qualitative studies report women's motivation to make healthy changes are driven by

a number of factors, most notably concern for the health of their unborn child; focus on their own health and a desire to become a good role model for their future child (Dencker et al., 2016; Rockliffe, Peters, Heazell, & Smith, 2021). In a study of 3868 pregnant women in Sweden, nearly 40% claimed they were dissatisfied with their lifestyle behaviours and wanted to improve their dietary behaviours, increase their physical activity and reduce their weight. Those with the greatest motivation to do so typically had a higher BMI and higher education level (Lindqvist, Lindkvist, Eurenius, Persson, & Mogren, 2017). Self-identity has also been shown to influence motivation to engage in lifestyle improvements in pregnancy. In their qualitative study of 17 pregnant women, Morris et al found that willingness to make healthy changes during pregnancy varied according to the extent to which women self-identified as 'healthy people'. They found that those at both extremes of the health spectrum were least likely to engage with support for healthy lifestyles, either because they had no interest (least healthy) or because they felt they needed no additional support (most healthy) (Morris et al., 2020).

Numerous studies have focussed on the barriers to healthy eating, physical activity and healthy weight gain in pregnancy, as documented in Vanstone et al's systematic review and meta-synthesis of 42 studies investigating pregnant women's perceptions of GWG (Vanstone et al., 2017). These barriers are summarised in Table 1-3. Some of these barriers such as lack of knowledge around the importance of a healthy diet and keeping active in pregnancy and the influence of social and cultural norms can be addressed through education and advice. As discussed in section 1.2.3, this is currently not always provided by HCPs. The physical and psychological barriers, such as nausea, hunger and cravings, can be debilitating and compromising to women's best intentions (Forbes, Graham, Berglund, & Bell, 2018).

Table 1-4: Barriers to healthy eating, physical activity and healthy weight gain in pregnancy

Type of barrier	Healthy eating	Physical activity
Knowledge	Lack of awareness of recommended GWG and risks of excessive GWG	
	Lack of understanding of the importance of healthy eating in pregnancy Limited skills to enable healthier eating (meal planning, shopping, cooking)	Lack of understanding of the importance of physical activity in pregnancy Lack of understanding about safe exercise/activity in pregnancy
Beliefs	Pregnancy is a vacation from worrying about weight Assume quick postpartum weight loss	
	Pregnancy is a time to eat for two Cravings/aversions are the body's way of communicating what mother and baby need/should avoid	Exercise in pregnancy is risky/can harm foetus Everyday activity and/or gentle walking is sufficient Pregnancy is a time for rest
Social and cultural norms	Pregnancy as a time to accept or celebrate weight gain	
	Pressure from family or friends to 'eat for two' Nutritional advice is not culturally relevant	Exercise not culturally acceptable for women Pressure from family to rest/avoid activity

Type of barrier	Healthy eating	Physical activity
Psychological barriers	Depression or stress leading to emotional eating Cravings Compensating for other deprivations (alcohol and cigarettes)	Depression or stress leading to inactivity/sedentary behaviour
Social support	Lack of emotional and practical support to adopt healthier behaviours	
Physical barriers	Nausea, vomiting and aversions Hunger and cravings Fatigue	Fatigue Joint pain, swelling, shortness of breath and awkwardness due to size
Practical barriers	Cost Lack of time Limited accessibility to healthy foods/prevalence of fast food	Sedentary job Weather prohibitive to outdoor activity Childcare

Note. Data extracted and tabulated from Vanstone et al, 2017

More recently, a large-scale qualitative study (n=74) identified the determinants of change in dietary and physical activity behaviours during pregnancy of both women and their male partners. (Versele et al., 2021; Versele, Stok, et al., 2022). Categorising the determinants of change across the layers of the socioecological model (i.e., across individual (including psychological, situational and biological), interpersonal, environmental and policy level), this study provides insight into how motivations and barriers underpin behavioural changes. The authors noted that whilst external factors such as social influence and home food availability can influence behaviour, most of the determinants of dietary and physical activity change operate at an individual level as a consequence of the physiological and psychological changes that pregnant women experience. They also referred to the 'pulling the pregnancy card' - a form of self-licensing where women give themselves permission to adopt less healthy behaviours because they are pregnant and deserve self-indulgence. Partners can play an important role in influencing dietary and physical activity behaviour change, although the authors reported that this can results in the adoption of less healthy behaviours (e.g. encouraging greater rest and sedentary behaviour and increasing portion sizes to feed the baby).

In summary, there is a complex mix of psychosocial, physical and structural barriers to eating healthily and being physical active in pregnancy. In order to be effective, a behaviour change intervention will need to harness the motivations to improve these behaviours whilst providing evidence-based strategies for overcoming the identified barriers.

1.6 Behavioural interventions to promote healthy eating, physical activity and weight management in pregnancy

1.6.1 Overview

The first comprehensive systematic review of RCTs evaluating the effect of dietary and physical activity interventions on GWG was published in 2012. Of the 28 studies included in this Cochrane Review, all but three took place after the turn of the century, reflecting both the growing prevalence of excessive GWG and the increased understanding of its effects on maternal and child health (Muktabhant, Lumbiganon,

Ngamjarus, & Dowswell, 2012). Since then, several systematic reviews have investigated the effectiveness and composition of interventions to prevent excessive GWG within various populations groups of pregnant women (Craemer, Sampene, Safdar, Antony, & Wautlet, 2019; Teede et al., 2022; Walker et al., 2018). Over the past two decades there has also been a proliferation of interventions focussing on improving physical activity levels in pregnancy (Cilar Budler & Budler, 2022; Currie et al., 2013; Flannery et al., 2019). Until recently, fewer have focussed on changing dietary behaviours independent of the goal of reducing excessive GWG, apart from interventions aiming to manage or prevent GDM which are not included in this thesis (Dawson et al., 2020; Van Dijk et al., 2016). However in the past 3 - 4 years, several interventions to improve adherence to the Mediterranean diet in pregnancy have been trialled (Crovetto et al., 2021; Papandreou et al., 2023; Zhang et al., 2021).

Many of these behaviour change interventions are complex, multi-component interventions that vary considerably in their design and delivery (Beulen et al., 2020). For example, dietary instruction given to participants can be general healthy eating advice, goal-related such as increasing fruit and vegetable consumption or decreasing consumption of take away foods, or following a specified diet such as the Mediterranean diet (Craemer et al., 2019). Similarly, physical activity components vary from group exercise classes to in-home physical activity plans, step counting and more general advice to keep active and avoid long sedentary periods (Chan, Au Yeung, & Law, 2019). This can make it challenging to identify which elements are most effective in achieving desirable improvements in healthy eating, physical activity and healthy weight gain in pregnancy.

To date, dietary and physical activity interventions in pregnancy have focussed primarily on the short-term goal of reducing excessive GWG. Less is known about the longer-term effect of these interventions in terms of resulting in enduring improvements to health behaviours. Whilst reducing excessive GWG is important, developing good dietary and physical activity behaviours in pregnancy may have potential of longer-term impact on obesity levels in current and future generations.

1.6.2 Use of theory in interventions to improve dietary and physical activity behaviours and/or reduce GWG

Interventions in this field have drawn on various behavioural theories, such as Control Theory, Social Cognitive Theory and the Theory of Planned Behaviour. Whether grounding an intervention in theory improves its effectiveness is contentious. Systematic reviews of interventions to reduce excessive GWG have reported mixed findings (Gardner, Wardle, Poston, & Croker, 2011; Hill, Skouteris, & Fuller-Tyszkiewicz, 2013). An umbrella review looking at health interventions more broadly reported no difference in effectiveness between those based on theory and non-theory based interventions (Dalgetty, Miller, & Dombrowski, 2019). However this may be attributable to other reasons, for instance poor application of theory to intervention development or inappropriate choice of theory, and therefore should not be used as an argument for dismissing the use of theory in intervention development (Davis, Campbell, Hildon, Hobbs, & Michie, 2015). Indeed, the Medical Research Council's (MRC) guidelines for developing complex interventions recommend starting with a 'pre-clinical' or theoretical phase before progressing to designing intervention components (Craig et al., 2008). In the past decade the Behaviour Change Wheel (BCW) has emerged as a popular tool for designing behaviour change interventions (Michie, van Stralen, & West, 2011). The BCW is built around the Capability-Opportunity-Motivation-Behaviour (COM-B) model of behaviour change and includes a taxonomy of 93 Behaviour Change techniques (BCTs). Together this model and taxonomy have led to greater consistency in reporting of behaviour change interventions, thereby helping intervention developers to identify techniques and logic models that are effective in changing dietary and activity behaviours during pregnancy (Hill et al., 2013; Michie, Abraham, Whittington, McAteer, & Gupta, 2009).

1.6.3 Effectiveness of physical activity and dietary interventions

Dietary and physical activity interventions to reduce rates of excessive GWG have been shown to be effective, with diet only interventions leading to greater weight reductions than physical activity only or combined interventions (Craemer et al., 2019; Teede et al., 2022; Walker et al., 2018). Meta-analyses have shown small reductions in GWG between 0.7 and 2.4 kilos when interventions are compared to standard care

(Fair & Soltani, 2021; International Weight Management in Pregnancy (i-WIP) Collaborative, 2017; Peaceman et al., 2018; Shieh, Cullen, Pike, & Pressler, 2018; Teede et al., 2022). Whilst statistically significant, these reductions are modest and it is unclear whether they are meaningful in terms of effect on maternal and child health outcomes. Indeed to date, evidence suggests that whilst dietary and physical activity interventions may be associated with reduced GWG, they have mixed effects on clinical outcomes. A meta-analysis of nearly 11,500 women showed reduced risk of excessive GWG (RR 0.80, 95% CI:0.73, 0.87) and of maternal hypertension in intervention groups compared to standard care, but no differences between groups with regard to pre-eclampsia, Caesarean delivery, macrosomia or shoulder dystocia (Muktabhant et al., 2015). A similarly sized meta-analysis of individual participant data reported lower GWG (mean difference −0.70 kgs, 95% CI:−0.92, −0.48) and reduced odds of Caesarean section of intervention groups compared to standard care, but yet again, no other statistically significant effects on maternal or offspring outcomes (International Weight Management in Pregnancy (i-WIP) Collaborative, 2017). A meta-review of 15 systematic reviews focussing specifically on women with overweight and obesity reported small reductions in GWG of 0.3 kgs to 2.4 kgs in lifestyle interventions compared to standard care and evidence of dietary only and physical activity only interventions leading to a reduction in the odds of GDM, but no other differences in maternal or foetal outcomes (Fair & Soltani, 2021). The most recent meta-analysis of 117 randomised clinical trials reported lifestyle interventions to be associated with reduced GWG (−1.15 kgs, 95% CI: −1.40, −0.91), reduced risk of GDM (OR 0.79, 95% CI: 0.70, 0.89), and of total adverse maternal outcomes (OR 0.89, 95% CI: 0.84, 0.94) compared to standard care (Teede et al., 2022). It is challenging to determine potential explanations for these seemingly conflicting findings, especially given the differences in statistical methods, studies included and outcomes reported. Whilst meta-analysis of individual participant data can be considered to produce higher quality evidence, in their study comparing aggregate data meta-analysis with individual participant data meta-analysis, Huang et al showed in almost 92% of comparisons (n=204) there was agreement in the overall effect (Huang et al., 2016). One possibility is that the more positive effects on maternal health reported in the Teede et al meta-analysis compared to i-WIP study may be related to the greater mean difference in GWG (-1.15 kgs in Teede et al. compared to -0.70 kgs in i-WIP). However, these are small differences, especially given the wide ranges of recommended GWG as prescribed by the NAM

guidelines (see Table 1-2). Further studies are needed to provide greater understanding of the relationship between GWG and maternal and child health outcomes.

It is interesting to note that most interventions use GWG rather than a behaviour (dietary and/or physical activity) as the primary outcome measure. In their systematic review of systematic reviews (n=109) exploring the effectiveness of behaviour change interventions in pregnancy Heslehurst et al. (2020) noted that whereas 100% of smoking and alcohol reviews reported maternal behaviour as the outcome, only 18% (16/89) of diet and/or physical studies reported these behaviours, with the majority measuring outcomes such as GDM and GWG (Heslehurst et al., 2020). By evaluating effectiveness based on outcomes further down the causal chain, other influences affecting the link between behaviour and outcome could be missed (Michie & Johnston, 2012). Moreover, knowing whether lack of intervention effectiveness is a function of inadequate behaviour change or a mis-identification of a behaviour as an underlying preventative mechanism in the health outcome is key to the development of effective interventions (Heslehurst et al., 2020).

Given the increasing understanding of diet quality on long term maternal and foetal health, insight into whether these interventions are effective in promoting dietary changes rather than simply reducing GWG would be valuable. Currently the paucity and heterogeneity of studies targeting dietary changes in healthy pregnant women means no meta-analyses have been undertaken (Hillier & Olander, 2017). Similarly heterogeneity of physical activity measures means meta-analysing data is challenging, although two systematic reviews have reported success of interventions reducing the decline of physical activity and increasing physical activity amongst women with overweight or obesity (Currie et al., 2013; Flannery et al., 2019).

1.6.4 Digital interventions targeting the reduction of excessive GWG and improving diet and physical activity in pregnancy

Traditionally early interventions relied solely on inter-personal methods of delivery (face-to-face or telephone). More recent programs have incorporated digital technologies to either support or replace inter-personal delivery. Although cost-

effectiveness analyses of these face-to-face interventions are infrequently performed and do not provide consistent findings, digital delivery is widely perceived to offer the advantages of scalability and cost effectiveness (Bailey et al., 2020; Carrandi et al., 2022; Murray et al., 2016). A recent systematic review investigating the cost effectiveness of mobile health interventions supporting women in pregnancy noted that all the studies took place from 2017 and concluded that whilst they can be cost effective, further research is needed to determine the cost savings associated with positive maternal and child health outcomes and longer term healthcare utilisation (Carrandi et al., 2022).

Digital interventions using apps, texts/SMS or internet have additional advantages over face-to-face interventions in that they are deliverable anytime, anywhere and can also be undertaken anonymously, thereby avoiding potential psychological barriers to participation. In non-pregnant populations, digital interventions have been shown to be effective in changing nutritional behaviours, encouraging weight management and improving levels of physical activity, although levels of effectiveness vary according to time period, population group and study setting (Beleigoli et al., 2019; Buckingham, Williams, Morrissey, Price, & Harrison, 2019; Islam, Poly, Walther, & Li, 2020; Stockwell et al., 2019; Villinger, Wahl, Boeing, Schupp, & Renner, 2019; Western et al., 2021). Evidence of their effectiveness to improve dietary and/or physical activity behaviours in pregnancy is mixed. Studies meta-analysing the effect of digital interventions in pregnancy on diet, physical activity and/or GWG first emerged in 2017, with four being published by the beginning of 2020 (Chan & Zhang, 2019; Lau et al., 2017; Sherifali et al., 2017; Walker et al., 2018). Two found no overall significant effect of the interventions (Sherifali et al., 2017; Walker et al., 2018), whereas one showed a significant result for limiting GWG ($z=2.85$, $p=0.004$) in women with overweight/obesity (Lau et al., 2017) and another a moderate effect ($d=0.45$, $p=0.003$) on managing GWG amongst women of all BMIs (Chan & Zhang, 2019). A systematic review of interventions using digital technology to support interpersonal delivery has also shown small but significant effect sizes of interventions on GWG ($d=0.23$), physical activity ($d=0.38$), energy intake ($d=0.38$) and eating behaviours ($d=0.16$) (Leonard, Evans, Oravecz, Smyth, & Symons Downs, 2020). A limitation of these meta-analyses is the considerable heterogeneity of the included studies, which weakens the validity of pooled data. To date, only one pilot RCT (n=54), the ‘SmartMoms’ study, has

compared interpersonal delivery with digital delivery of the same intervention. This multi-component intervention targeted diet, physical activity and weight monitoring, using 18 lessons and functions to enable self-monitoring of all three outcomes and deliver personalised feedback. Whilst the intervention was effective via both delivery methods, the digital arm was lower in cost for participants and clinics, and showed greater participant adherence (Redman et al., 2017).

In summary, digital interventions appear to have potential to be effective in improving dietary and physical activity behaviours in pregnancy and reducing the risk of excessive GWG, with even small effect sizes being meaningful at a population level. Focussing on diet quality rather than simply GWG seems important given the increasing understanding of the direct impact of diet quality on maternal and infant health outcomes. Determining the key ingredients of an effective digital intervention is challenging given the heterogeneity of intervention designs. Meta-analyses suggest that digital interventions are less effective that in-person interventions, pointing to the inclusion of an interpersonal element as a potential means of improving effectiveness of digital interventions. For exclusively digital interventions, other ways of compensating for the lack of interpersonal contact will need to be identified.

1.7 The Baby Buddy story

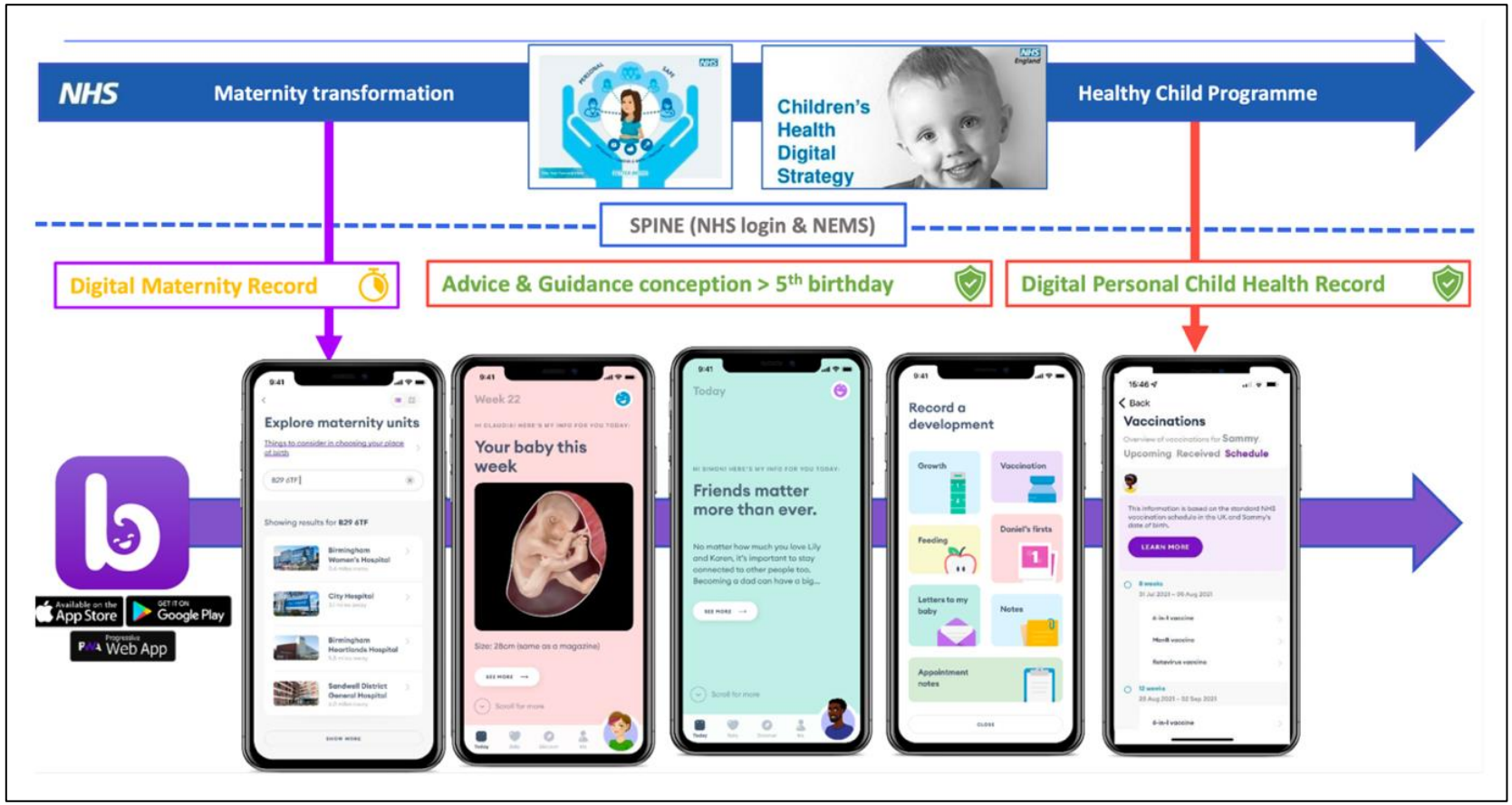
Baby Buddy is a freely available, non-commercial (advert-free) UK pregnancy and parenting smartphone app that guides and supports parents and caregivers throughout pregnancy and their baby's first year of life. The app provides users with their own 'digital best friend', interactive features, over three hundred films and signposting to 24/7 support. Each day users receive a bite-size personalised message containing information relevant to their stage of gestation or baby's age. These messages cover foetal/baby development, maternal health and well-being, bonding and attunement, relationships and more. Most messages also include a link to other written or film content for more detailed information or similar topics, allowing the user to personalise the way they engage with materials.

The original version of Baby Buddy was developed by UK charity Best Beginnings with funding from the Big Lottery and was launched in 2014. A new version, Baby Buddy

2.0, funded by the National Lottery Community Fund and the Fidelity Foundation, a private, non-operating foundation committed to building capacity for non-profit organisations, was launched in 2021. Baby Buddy 2.0 (see Figure 1-1) includes a dedicated content pathway for fathers/co-parents and capacity for new content and functionality that can be unlocked for subsets of app users based on their locality, characteristics or participation in a study or trial. Extensive qualitative research was undertaken in the development of both versions of Baby Buddy along with workshops and ad hoc input from perinatal HCPs.

Baby Buddy is endorsed by eight Royal Colleges and Professional Bodies and is integrated into the maternity care pathways of around 50 NHS Trusts and Care Commissioning Groups (CCGs) across the UK. An Editorial Board consisting of representatives of these endorsing organisations and special advisors in the UK, reviews, comments on and approves all new content before it is uploaded to the app. Additionally, all Baby Buddy content is regularly reviewed and updated in line with Best Beginnings' commitment to best practice. A review of UK pregnancy apps in 2019 found that of 29 apps evaluated, only two, one of which was Baby Buddy, fulfilled all accountability criteria and contained no inaccurate information (Bland et al., 2020).

Figure 1-1:Baby Buddy 2.0 App



Abbreviations:

SPINE: NHS IT infrastructure

NEMS: The National Events Management Service, enables sharing of patient health information in near real-time

Baby Buddy is free to download from the NHS app library, the App Store and Google Play. Whilst some users come to it through these routes, others are introduced to the app by their HCP. Best Beginnings offers an embedding and training programme to NHS Trusts and CCGs whereby a plan is co-created and delivered to integrate Baby Buddy into the maternity care pathway. In this way HCPs can encourage their patients to use the app in general as well as target specific goals such as smoking cessation, maternal mental health or appointment adherence. To date (September 2023) nearly 500,000 users have registered on Baby Buddy in the UK. An independent evaluation of the embedding process reported largely positive views from users and HCPs, and concluded that the resources can be beneficial for families (Crossland, Thomson, & Moran, 2019).

Baby Buddy adheres to the principle of proportionate universalism; although it is available to all UK expectant and new parents, it was created to be particularly relevant to and engaging for parents from socially and/or economically disadvantaged communities whose children are at higher risk of poorer health and developmental outcomes (Marmot, 2010). As such its written content intentionally has a literacy age level of 9 years and film is used extensively as a communication medium. Peer-to-peer films play a particularly important role in communicating important health messages in a non-authoritarian and accessible way. Films also help to reinforce a sense of inclusivity by portraying expectant and new parents from a range of ethnic and racial backgrounds. In addition, the Baby Buddy Local model provides an opportunity for local maternity systems to assess their priority health needs and groups and tailor the use of Baby Buddy to address specific needs and health inequalities within a locality (Best Beginnings, 2023). Baby Buddy 2.0 data to March 2023 show that it is reaching communities with the greatest need: almost 30% of users live in households with an annual income of under £25000; 28.1% of users are from Black, Asian, Mixed or other ethnic minorities and 11% of users report that English is not their first language (this compares to 7.7% of pregnant women in the UK whose first language is not English).

Best Beginnings believes in collaborating with academic and third sector organisations to further its commitment to providing evidence-based resources for expectant and new families. In response to the COVID-19 pandemic, Best Beginnings undertook a rapid research project with UCL to understand the impact of lockdown on expectant

parents and those with young children, and to determine how Baby Buddy could best serve its users under these circumstances (Rhodes et al., 2020). This project became the starting point for Babies in Lockdown, a collaborative initiative between Best Beginnings, the Parent-Infant Foundation and Home-Start UK ("Babies in Lockdown," 2020).

1.8 Baby Buddy and behaviour change

The Baby Buddy app is a complex and multi-focussed behaviour change tool, encouraging and supporting a wide range of behaviours relating to self-care (emotional and physical), infant care and relationships. Independent research has shown Baby Buddy to significantly improve mother - infant bonding (Crossland, Thomson, & Moran, 2020). Post hoc analysis of a multi-site cohort study evaluating the effectiveness of the Baby Buddy app amongst first time mothers reported Baby Buddy users were more likely to be breast feeding at one week, 3 weeks and 3 months post birth than non-Baby Buddy users (Deave et al., 2019). Although user research underpinned the development of Baby Buddy and its content, formal behaviour change theory was not applied. A study retrospectively applying the BCW to breast feeding content in Baby Buddy concluded that the inclusion of BCTs particularly in the video content and the co-creation process (with end users as well as HCPs) might explain its positive effect on behaviour change (Musgrave, Baum, Perera, Homer, & Gordon, 2021).

A generic behaviour change feature called "You can do it" was included in the original Baby Buddy. Users were able to set their own goals, create reminders to carry out the behaviours they selected and record their achievements. Suggestions were given, such as 'remember to drink a glass of water'; 'remember to do my pelvic floor exercises' and 'remember to take my vitamins'. Rather than transfer this feature to Baby Buddy 2.0, Best Beginnings elected to design new functionality for Baby Buddy 2.0 which could be used for various behaviour change interventions for perinatal and infant health and well-being. This led to a collaboration between Best Beginnings and UCL to develop, build and evaluate a theory-based behaviour change intervention targeting diet and physical activity to encourage healthy GWG – the subject of this thesis. The new functionality created within the app as a result of this collaborative venture will be

used for other behaviour change interventions targeting, for example, perinatal mental well-being, smoking cessation and weaning.

1.9 Summary

Maternal obesity and excessive GWG are a public health challenge both as a consequence of their association with adverse health outcomes during pregnancy and labour, and their impact on weight gain trajectories for mother and child. Studies suggest that pregnant women are motivated to make behaviour changes to enhance the health and well-being of their unborn child, indicating that an opportunity exists to encourage better dietary and physical activity behaviours, although physical, psychological, social and structural barriers will need to be addressed. Interventions targeting diet and physical activity have been successful in changing behaviours and reducing GWG. Current literature provides only limited insight into why some of these interventions are more effective than others. A greater understanding of what drives their effectiveness is needed if effect sizes are to be increased. Digital interventions offer the advantages of scalability and cost effectiveness. As an existing pregnancy and parenting app used within the NHS, Baby Buddy presents an ideal channel through which to deliver a public health intervention to improve dietary and physical activity behaviours and promote healthy weight gain in pregnancy.

Chapter 2 Aims and objectives of the thesis

2.1 Overall aim

The overall aim of this thesis was to develop a digital intervention to encourage healthy eating, physical activity and healthy weight gain in pregnancy for the Baby Buddy app. The evidence as discussed in Chapter 1 indicates both the need for and potential of a digital behaviour change intervention to address poor dietary and physical activity behaviours and excessive weight gain in pregnancy. Furthermore, Baby Buddy, an existing pregnancy and parenting app used within the NHS, is an ideal platform through which to deliver a behaviour change intervention to expectant parents.

2.2 Research objectives

In achieving the overall aim outlined above, four specific research objectives were identified as follows:

1. To learn from existing digital antenatal interventions focusing on healthy eating, physical activity and GWG by examining their overall effectiveness and identifying key drivers of their effectiveness.
2. To understand expectant parents' views on a feature within a pregnancy app to encourage and support healthy eating, physical activity and healthy weight gain.
3. To identify barriers to using such a feature and determine how these can be overcome to ensure good uptake and sustained engagement.
4. To use the knowledge derived from objectives 1-3 to design a theory-based digital behaviour change intervention to encourage and support healthy eating, physical activity and healthy weight gain in pregnancy.

Study 1 aimed to investigate overall effectiveness of existing digital interventions targeting diet, physical activity and weight gain in pregnancy in order to determine their overall effectiveness and to identify the drivers of effectiveness (Objective 1.). This study is reported in Chapter 4.

Study 2 aimed to explore user-response to the concept of an app-based intervention aimed at expectant couples and targeting diet, physical activity and weight gain in pregnancy. The study investigated the facilitators and barriers to participating as a couple and explored reactions to a rudimentary intervention concept and generated ideas for its development (Objectives 2. and 3.). This study is reported in Chapter 5 and Chapter 6.

Study 3 aimed to explore the user-response to a developed intervention design, the BaSHH intervention. An iterative approach enabled a cycle of content and design development and evaluation (Objective 4.). This study is reported in 0.

Study 4 aimed to test the feasibility of a prototype of the intervention feature, giving insight into reactions to the user interface and the user experience (Objective 4.). This study is reported in Chapter 9.

2.3 Personal motivation

My motivation for starting this PhD was born out of a desire to use the skills and knowledge I had built up over a long commercial research career to address the current public health crisis relating to poor dietary and physical activity behaviours.

For nearly 30 years I worked as a commercial qualitative researcher specialising in new product development, and brand and advertising strategy development. Working with large national and international companies primarily in food manufacturing, retailing and service industries, I witnessed the power of advertising and marketing to influence consumer attitudes and purchasing behaviour. In the 1980s and 1990s developing new confectionery products, savoury snacks and ready meals felt a positive step - giving the consumer greater choice and convenience. However with hindsight, such trends were clearly fuelling the emerging obesity epidemic. In 2010 a chance meeting with Alison Baum, CEO of Best Beginnings, led to me working with the charity on a pro bono basis. For 8 years I conducted the charity's consumer insight research, helping to design and launch new resources for pregnancy and early parenthood. Initially these resources were DVD based, but by 2012 we identified the

opportunity for a pregnancy and parenting app. After several stages of qualitative research, the Baby Buddy app was launched in 2014.

During this period, I was also volunteering with Home-Start, a UK wide charity that connects volunteers with local vulnerable families, many of whom have children identified as ‘at risk’ by social services. Amongst other things, this gave me insight into the dietary attitudes and behaviours of families living on very limited incomes. I worked with my local Home-Start branch to develop and run weekly classes to teach young parents basic cooking skills and how to eat a healthily on a budget. Whilst this initiative was very popular and successful, we could only ever reach a small number of families. I was keen to explore the idea of using Baby Buddy as a vehicle through which to deliver information and support to expectant and new families about healthy eating. Meanwhile Best Beginnings was becoming increasingly aware of concerns around maternal obesity being voiced by the healthcare providers they were working with, so when I proposed the idea of a behaviour change intervention to support healthier dietary behaviours and manage GWG, Best Beginnings responded enthusiastically and the journey towards this PhD began.

Chapter 3 Methods

3.1 Overview and approach

Figure 3-1 summarises the intervention design and development process and the four key studies within this thesis. Consistent with guidance for the development of complex health interventions from the MRC, the National Institute for Health Research in the UK and Best Beginnings' approach, the intervention development was a collaborative, person-based and iterative process, built on a sound evidence base and rooted in theory (O'Cathain et al., 2019; Yardley, Morrison, Bradbury, & Muller, 2015).

Study 1 was a systematic review and meta-analysis that investigated existing digital interventions targeting diet, physical activity and weight gain in pregnancy in order to determine their overall effectiveness and to identify the intervention elements that characterised effectiveness.

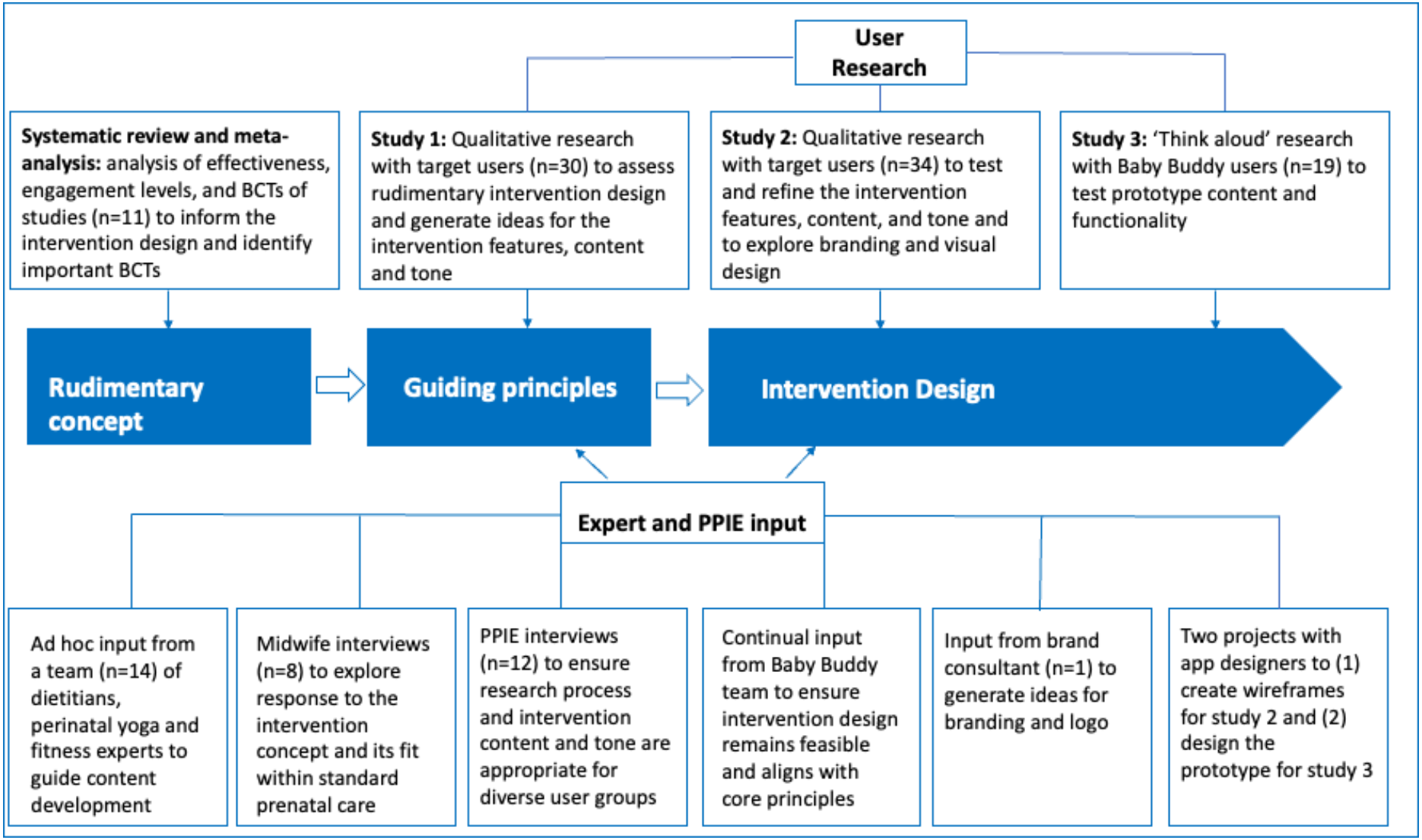
Study 2 used a qualitative design comprising focus groups and individual interviews amongst expectant parents and parents of infants up to 18 months old. The COVID-19 pandemic necessitated a deviation from the original study protocol of face-to-face interviews to remote interviews. Hence the focus groups were conducted on the video conferencing platform Zoom and the individual interviews were conducted by telephone.

Study 3 comprised a series of individual and couple-based interviews conducted on Zoom. Once again, participants were either expecting a baby or had an infant under 18 months old. An iterative approach was adopted, so that changes made to the intervention design and content could be explored in subsequent interviews.

Study 4, again comprising a series of qualitative interviews, used a 'Think Aloud' interview technique to gauge participants' response to the intervention prototype. All participants were current Baby Buddy users.

The detail of the study methodologies are reported in the study chapters 4-7 and 9.

Figure 3-1:Overview of PhD methodology



Throughout the course of these studies, regular meetings were held with the Best Beginnings team, stakeholders and the Personal and Public Involvement (PPIE) group. Experts within the fields of nutrition and physical activity provided ad hoc input into the intervention content development and helped to create a series of short videos to support the intervention messages. In line with Best Beginnings' commitment to best practice, all intervention content was reviewed by the Editorial Board, which consists of representatives of key health organisations in the UK.

Once the proposed intervention concept design had been agreed upon, app designers and brand consultants were engaged to develop the concept from initial ideas to constructing a prototype and ultimately creating the final intervention design.

3.2 Approach, framework and theory for the intervention development

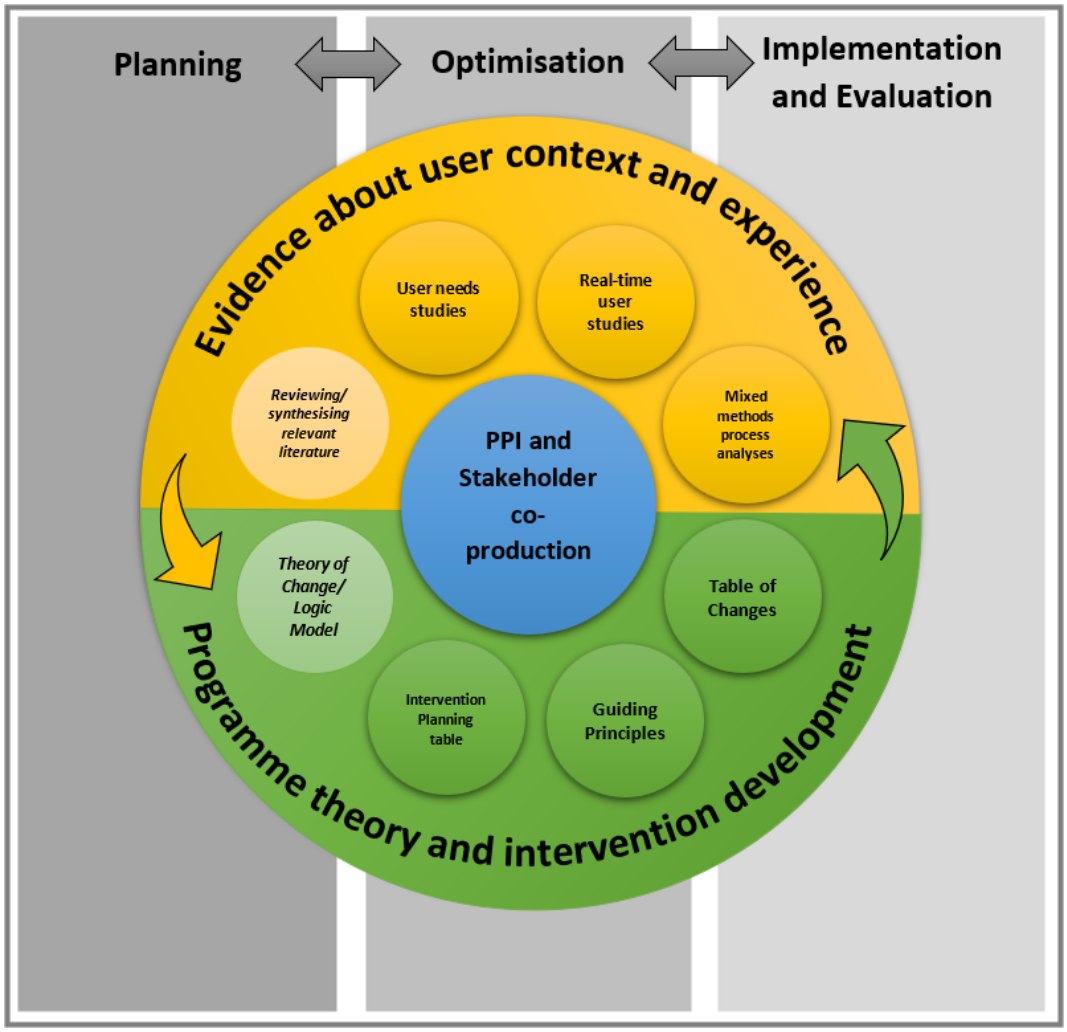
3.2.1 The Person-Based Approach

The Person-Based Approach (PBA) is an iterative method for planning, optimising, evaluating and implementing behavioural health interventions. The PBA evolved as a learning process through the development of over 50 interventions and has been validated by the effectiveness of interventions developed using this approach (Yardley et al., 2015). It was chosen for this study as it was felt to combine the rigour of an academic approach, in particular using theory as a basis on which to build a behaviour change intervention, with a user-led approach, more familiar to Best Beginnings and on the basis of which the Baby Buddy app was created. The PBA to intervention development stresses the importance of understanding and being guided by the needs and experiences of end-users of the intervention (Yardley et al., 2015). As such it advocates research, typically qualitative, with target users, as well as PPIE input. The PBA also suggests tools, such as the Guiding Principles and the Table of Changes, which can be used to ensure a cohesive intervention process built on consensus within the team, as illustrated in Figure 3-2.

The Guiding Principles ensure that all members of the development team and wider stakeholder group agree on the key goals of the intervention and how these might be

achieved. They draw on a deep understanding of the target user and focus on how the intervention will be engaging - enjoyable, meaningful and persuasive. Whilst the Guiding Principles act as a specification for the intervention, they are not fixed and can be revisited and refined during the development process. The Guiding Principles for this project were agreed with Best Beginnings after the completion of Study 2 (see Figure 7-1).

Figure 3-2: The Person-Based Approach



Note. This figure is taken from The Person-Based Approach website ("Person-Based Approach (PBA) - PBA Overview Diagram," 2015)

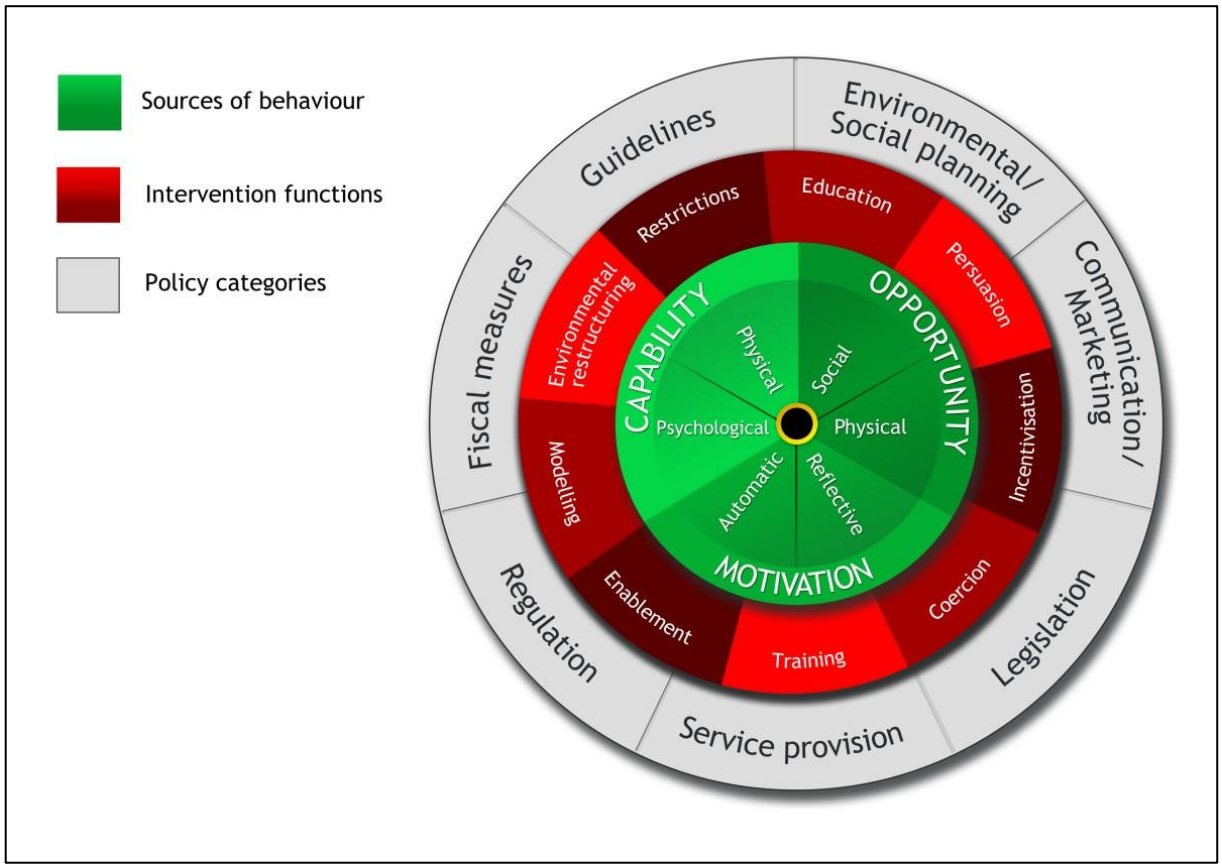
The Table of Changes is used to systematically record proposed and actual changes to an intervention during its development phase. All positive and negative comments emerging from user research that might impact the intervention design are logged,

along with a ranking of importance that a corresponding change is made and reasons for this change. The ranking is based on the MoSoCoW project classification system (MUST have, SHOULD have, COULD have, WOULD like to have) (Clegg & Barker, 1994). 'MUST have' is defined as those requirements critical to the success of the intervention, with the degree of importance diminishing through to 'WOULD like to have'. A further level of coding records why the proposed changes are important. The categories used are 'important for behaviour change'; 'easy and uncontroversial'; 'repeatedly reported'; supported by experience'; 'does not contradict the literature, experience or Guiding Principles' and 'not changed'. A Table of Changes was used to collated and action the findings of Study 3 (see Appendix 12). Both the Guiding Principles and the Table of Changes are elements fundamental to the PBA to health behaviour intervention development.

3.2.2 The Behaviour Change Wheel and COM-B

The BCW was used as the main underlying framework for the development of the intervention. As a comprehensive and conceptually coherent framework, it provides a solid starting structure around which to develop a behaviour change intervention. It was developed from a systematic review of 19 behaviour change frameworks, none of which was deemed to be sufficiently comprehensive (Michie et al., 2011). The BCW comprises three layers. At the heart of this framework is the COM-B model of behaviour change. This is surrounded by 9 intervention functions and the outer layer comprises seven types of policy that could be used to deliver these functions (see Figure 3-3).

Figure 3-3: The Behaviour Change Wheel

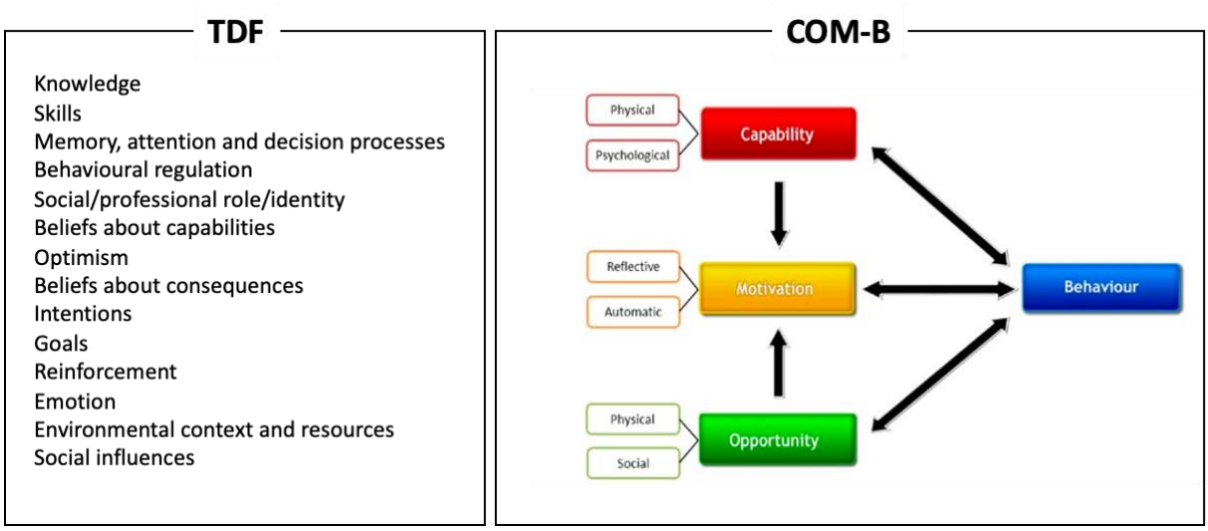


Note. This figure is taken from The behaviour change wheel: A new method for characterising and designing behaviour change interventions (Michie et al., 2011)

Given the a priori decisions to develop a behaviour change intervention to sit within the Baby Buddy app, the outer layer of the BCW was not relevant to this project and the main utility of the BCW was in using COM-B to identify, select and design appropriate BCTs. The COM-B model postulates that for behaviour change to occur, an individual needs to have the capability (C), opportunity (O) and motivation (M) to change their behaviour (B). Capability is defined as both the physical and psychological capacity to perform the behaviour; opportunity is the physical resources and social support to make the behaviour possible, and motivation is the desire to want to perform the behaviour, both at a reflective and automatic level. The Theoretical Domains Framework (TDF), recognising the importance of behavioural theories and theories of behaviour change in developing evidence-based interventions, is a synthesis of key theoretical constructs from 33 theories. Comprising 14 domains, it adds an extra layer of granularity to COM-B (Cane, O'Connor, & Michie, 2012) (See

Figure 3-4). It was used in this thesis to inform the focus group and interview questions and analyse and the research findings.

Figure 3-4:COM-B Model and the Theoretical Domains Framework



Note. Adapted from Michie, Atkins, & West, 2014.

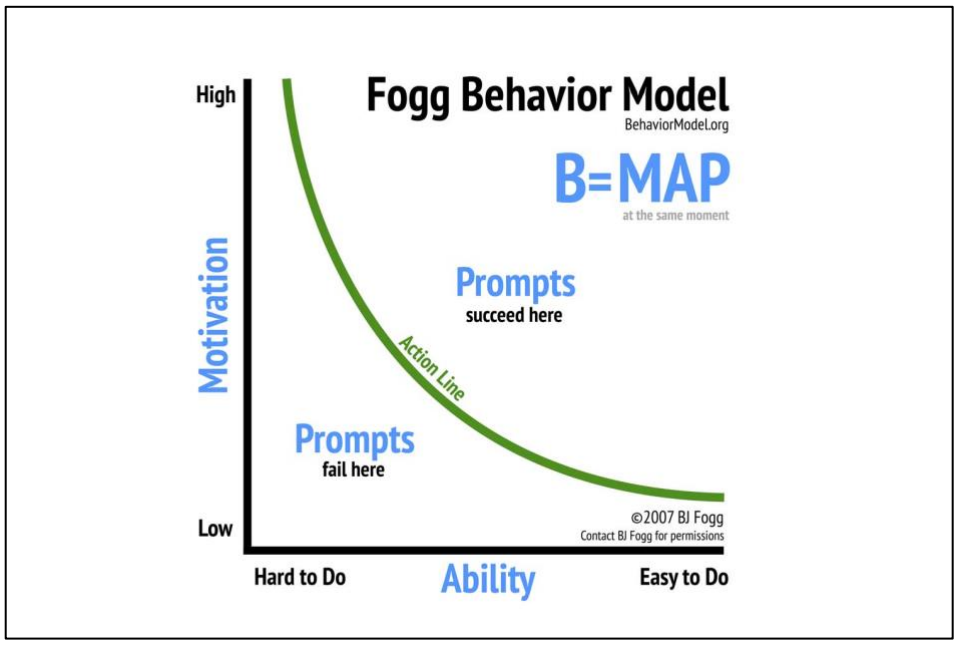
The BCW also comprises a taxonomy of 93 BCTs. A BCT is defined as "a systematic procedure included as an active component of an intervention designed to change behavior" that is observable, replicable and irreducible (Michie et al., 2011). The taxonomy allows intervention developers to systematically and thoroughly identify the BCTs which might be relevant and effective to their intervention. As such it has helped intervention developers identify techniques effective in changing dietary and physical activity behaviours (Hill et al., 2013; Michie et al., 2009; Soltani, Arden, Duxbury, & Fair, 2016). Although this taxonomy provides a detailed description of each BCT, it does not account for the variation in the design and delivery of the BCT. This limits its usefulness in designing the BCTs used within an intervention. It also needs to be considered when assessing the role that individual BCTs play within an intervention, as it is the design and delivery of a BCT as well as the BCT itself that affect how users interact with it and its consequent effectiveness.

3.2.3 Fogg Behaviour Model

Many of the interventions to promote healthy eating and physical activity in pregnancy have focussed on short-term GWG and not investigated the long-term behaviour

change effects, despite the life-long relevance of these positive behaviours to the health of all members of the new family. If healthier dietary and physical activity behaviours developed during pregnancy were to become lasting habits – i.e. context-cued, impulse-driven behaviours as opposed to behaviours driven by conscious motivational processes - then the benefits of such interventions may extend well beyond maternal and foetal health into family life stages. Many of the techniques associated with behaviour change, such as goal setting, action planning, self-monitoring and problem solving, are relevant to habit formation too, the key difference being the use of event-based cues (e.g. getting into a car) to develop context-dependent action (putting on a seat belt) is specific to habit formation (Gardner, & Rebar, 2019). For these reasons the development of this intervention also drew on the Fogg Behaviour Model (FBM) (Fogg, 2009). This model proposes that for a behaviour to happen, three elements, motivation, ability and prompt (or trigger) must occur at the same time. Motivation and ability have a compensatory relationship such that when ability is low or the behaviour is hard to do, high motivation can help to make the behaviour achievable and, similarly, at times of low motivation behaviour is more likely to occur if the behaviour is easy to do – i.e. high ability (see Figure 3-5).

Figure 3-5: Fogg Behaviour Model



Note: Adapted from A Behavior Model for Persuasive Design (Fogg, 2009).

The Fogg Behavior model differentiates between times of high and low motivation at the individual level. When motivation (y-axis) is high (for example on day one of a new diet) challenging behaviours can be undertaken that will help reduce barriers and structure future behaviour. At times of low motivation (for example after several days into the new diet when no significant weight loss is apparent) simple or tiny behaviours provide a more realistic solution. Based on this, Fogg's Tiny Habits® Method is a simple approach to developing new habits, that involves users creating a Tiny Habits Recipes using the formula "After I (Anchor Moment) I will (Tiny Behaviour), for example 'after switching the kettle on, I will do 5 squats'. Consistent with habit theory, each tiny behaviour should be anchored in an existing routine or event. Additionally the Tiny Habits Method states that the completion of a tiny behaviour should be followed by an instant celebration to reinforce a feeling of success and self-efficacy (Fogg, 2020). Fogg defines an instant celebration as something you think, say or do to make you feel positive. It can be as simple as saying 'nice one!' This positive emotion helps to reinforce the habit.

Given the barriers that face pregnant women in trying to achieve healthy eating and physical activity goals (see Table 1-4) a model that recognises and provides strategies for times of low motivation was deemed to be particularly relevant for this target population. A further advantage of the FBM is that unlike COM-B, the Tiny Habits Recipe provides a detailed blueprint for designing the goal setting BCT.

A free 5-day Tiny Habits course online is supported by numerous positive testimonials from coaches using this method and individuals who have successfully changed their behaviour. However, unlike the BCW that has been used extensively in the development of health interventions, published literature on the use of FBM and Tiny Habits is sparse (Hollingsworth & Redden, 2022; Militello, Mazurek Melnyk, Hekler, Small, & Jacobson, 2016).

Combining elements of both Com-B and the Tiny Habits Method, Gardner et al. (2021) highlighted the need to disrupt habit associations if long term behaviour change is to be achieved. (Gardner et al., 2021). The authors identified three BCTs that are core to habit substitution and as such may lead to longer lasting habitual behaviours – habit

reversal, behavioural substitution, context-dependent repetition. They also suggested a further three BCTs that can support efforts to enact new responses to habit cues - use of prompts or cues, action planning, conserving mental resources.

3.3 Stakeholder and Public Involvement and Engagement (PPIE)

Regular collaboration with stakeholders and members of a PPIE group ensured that the intervention design met the needs of a wide and diverse user group.

NHS Surrey Heartlands CCG was one of the first CCGs to embed Baby Buddy 2.0 within its maternity care pathway when this new app version was launched in 2021. In early discussions in 2019, this CCG raised a particular concern around maternal and childhood obesity and expressed a desire to support the development of an antenatal healthy eating and physical activity intervention. The plans for this PhD were presented to Surrey Heartlands' antenatal steering committee and the CCG agreed to contribute to the funding of Studies 3 and 4 of this PhD. The CCG also agreed to take part in piloting the intervention before it is eventually included as a standard feature of Baby Buddy. Regular meetings throughout the intervention development process and specific input from clinicians working within maternal and child health ensured that the intervention was aligned with Surrey Heartlands' needs and expectations, in addition to achieving the main aims of the intervention.

A PPIE group was recruited after the completion of Study 1, comprising individuals (n=12) from healthcare and grass-roots organisations supporting particular groups and/or aspects of perinatal health (n=8/12) and parents (n=4), two of whom had used the Baby Buddy app. The group included the founder of a black maternal health organisation and the founder of a support group for pregnant women living with obesity; a father's mental health and parenting coach; a psychotherapist and coach for health and relationships; two members of different parenting organisations (one in Birmingham and one in East London) supporting minority ethnic communities; two members of an organisation promoting active family lifestyles; four parents one of whom was in a same sex relationship, one of whom was a single parent and three of whom were non-White ethnicity. Individual online discussions with PPIE group members took place twice between Studies 1 and 3, with all participants attending at

least one session and 6 participants attending both. These interviews provided invaluable insights into the needs and views of minority ethnic groups, women with obesity, the experience of pregnancy as a same sex couple, single parent. and an expectant dad. Participants were asked for their views on the intervention concept which helped to shape the intervention content and provide ideas for exploring in the user research. PPIE participants also contributed to the design of the topic guides for user research by providing preliminary feedback on the intervention concept and insights into how best to explore sensitive subjects with research participants.

Additional stakeholder interviews were conducted with midwives (n=8) to explore their views of the intervention concept and how they would envisage it fitting into established antenatal care pathways in the UK. These interviews took place between Studies 2 and 3. The sample included midwives who provided tailored services to pregnant women with obesity and those at risk of and already diagnosed with GDM.

3.4 Target population and recruitment strategy for the user research

Consistent with Best Beginning's philosophy of proportionate universalism, the intervention was designed for all expectant parents but with an emphasis on those from seldom heard communities – that is those whose voices are less likely to be heard by professionals and decision-makers and who are represented less in research - including minority ethnic groups, young expectant parents, those without post-school qualifications, those for whom English is a second language and lower income groups. Since these groups are so often under-represented in research, special emphasis was placed on ensuring their voices were heard at each stage of the research. In order to achieve this, a professional research recruitment agency, Apogee Group Recruitment, was engaged to assist with participant recruitment for Studies 2 and 3. Apogee Group Recruitment maintains an extensive data base from which they select potential participants to take part in focus groups or interviews, based on criteria agreed with the researcher. The company specialises in recruiting participants from ethnic minority communities. Whilst this form of recruitment can be costly, it ensured that the profile of the research samples reflected the target users of the intervention.

3.5 Analysis methods

Analysis methods differed across the four studies and are described in detail within their respective chapters.

3.6 Reflexivity statement

In all qualitative research, the effect of the researcher, the research setting and the context of the research should be acknowledged and taken into consideration when interpreting the findings. This is particularly pertinent given the significant role I had in shaping and conducting the project: I led on the development of the recruitment strategy, I designed the qualitative interview guides, I conducted the majority of research interviews and I undertook the majority of the analysis and interpretation of the data. This might have resulted in my failure to capture all the factors relevant to the project and all the issues that participants wanted to discuss. However, I aimed to create a safe space in which participants felt comfortable to talk openly and freely. Within the bound of the topic area I allowed participants to lead on the order and content of the discussion and I encouraged them to generate their own ideas rather than simply respond to those shown to them.

As a white, middle-class woman, at least one and often two generations older than participants, my distance from the target audience presented advantages and disadvantages. Whilst it allowed participants to share their experiences of pregnancy with me as an outsider, knowing that I was not drawing comparisons with my own current experiences, participants might also have felt that I was distanced from them and therefore unable to truly understand and empathise with them. That I was developing an intervention to encourage healthy eating and physical activity clearly indicated to participants my belief in the importance of healthier behaviours. I was fully aware of the potential of this to create a perceived imbalance of power – that participants might feel pressured to present a more health-conscious version of themselves or hide economic and social pressures that force them to make less healthy choices. Many years of conducting focus groups and interviews has taught me ways in which to minimise the power differentials between researcher and participant and create a non-judgemental and safe environment in which participants feel able to

express their views honestly and openly. Most importantly, frank and open discussions with my PPIE team helped me explore how I might be perceived by participants, particularly those from minority groups that I was obviously not a member of, and how best to approach the interviews and focus groups.

In Studies 3 and 4 a UCL Health Psychology MSc student, Arya Pimprikar, moderated some of the interviews and contributed towards the analysis. As a South Asian in her early 20's, Arya brought a different perspective to the research. During our weekly meetings throughout the two studies we discussed the effect of our own backgrounds and experiences on the interviews we had completed and our analysis of the findings. On the few occasions that our interpretations differed, we sought to understand the roots of this divergence and identify a mutually satisfactory solution for resolving these differences.

Conducting interviews and focus groups online presents challenges and opportunities and again, these need to be considered in the interpretation of the findings. One benefit is that participants can feel a greater sense of control, the interview often being at a time of their choosing and in their own home. However the ability to read non-verbal signals is constrained and interaction between participants in focus groups is restricted.

3.7 Ethics and standards

Approval for this programme of research was granted by University College London Research Ethics Committee (16749/001 and 16749/002). Participants in all stages of research provided informed consent as necessary.

Chapter 4 Study 1: Systematic review and meta-analysis of exclusively digital interventions targeting healthy diet, physical activity and weight gain in pregnancy[2]

This chapter reports on Study 1, the overall aim of which was to learn from existing digital antenatal interventions focusing on healthy eating, physical activity and GWG by examining their overall effectiveness and identifying key drivers of their effectiveness. Study 1 was a systematic review and meta-analysis of exclusively digital interventions targeting healthy diet, physical activity and weight gain in pregnancy. The study aimed to investigate overall effectiveness of the interventions on diet, physical activity and GWG; to examine the use of BCTs and to explore user-engagement. From the results I was able to conclude that whilst these exclusively digital interventions are currently less effective than similar interventions delivered in-person, they can be effective if high engagement with key BCTs is achieved. This study helped me to identify which BCTs will need to be included in the intervention design, as well as potential strategies for encouraging user-engagement.

4.1 Introduction

Whilst several recent systematic reviews and meta-analyses have studied the effectiveness of digital interventions on managing GWG (see 1.6.4), these have typically not distinguished between interventions using digital technologies alongside face-to-face delivery and those depending exclusively on digital interventions (Chan & Zhang, 2019; Lau et al., 2017; Sherifali et al., 2017; Walker et al., 2018). The difference is an important one for healthcare providers as the broader reach, lower costs and less demand on staff resources required to implement and deliver an exclusively digital intervention makes it an attractive option in comparison to an interpersonal intervention, provided of course, it is effective. Cost and time benefits of

[2] A version of Study 1 has been published in JMIR. Rhodes A, Smith A, Chadwick P, Croker H, Llewellyn C. Exclusively Digital Health Interventions Targeting Diet, Physical Activity, and Weight Gain in Pregnant Women: Systematic Review and Meta-Analysis. JMIR Mhealth Uhealth 2020;8(7):e18255 URL:https://mhealth.jmir.org/2020/7/e18255 DOI: 10.2196/18255.

a digital intervention extend to users too, as the intervention can be followed at home and at a time to suit the user. Moreover, the privacy a digital intervention affords might reduce the psychological hurdle to engagement for potential users. An exclusively digital intervention can emulate the delivery model of self-directed health behaviour apps such as weight loss and activity tracking apps, which are increasingly becoming an accepted and go-to format.

None of the systematic reviews and meta-analyses referred to above investigated user engagement, a vital component of self-managed digital interventions (Yardley et al., 2016). Additionally, none explored the BCTs used in the digital interventions. Since it cannot be assumed that BCTs have equal relevance to and effectiveness across different intervention delivery methods, a review focussed specifically on the role of BCTs in digitally delivered interventions for this population is a unique contribution to the literature.

In recognition of these research gaps, I decided to conduct a systematic review and meta-analysis of exclusively digital antenatal dietary, physical activity and weight management interventions, investigating user engagement and BCTs in addition to intervention effectiveness.

4.2 Aims

The aim of this systematic review was threefold: (1) to determine the effectiveness of exclusively digital diet and physical activity interventions to improve these behaviours and/or to avoid excessive weight gain in pregnancy; (2) to investigate user engagement with the interventions and (3) to identify and assess usage of BCTs within the interventions.

4.3 Methods

This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Moher, Liberati, Tetzlaff, Altman, & Group, 2009) and was registered with PROSPERO (CRD42019124838).

4.3.1 Search strategy

A search of six literature databases, Medline, PsychInfo, Embase, CINAHL, Web of Science and ProQuest Dissertations and Theses was conducted in February 2019 to identify relevant studies. Advanced searches of key words and index terms covered four concept areas (pregnancy status, diet or physical activity intervention, digital technology and study design), and were tailored according to each database (see Appendix 1). The Cochrane library was also searched for related systematic reviews and their reference lists, along with those of eligible studies, were hand-searched. Once duplicates had been removed, studies were screened and assessed for eligibility based on title and abstract. A secondary and independent screening and assessment was undertaken by Dr Paul Chadwick (PC), a co-author on this study.

4.3.2 Inclusion and exclusion criteria

Studies were included in the study if they fulfilled the following PICOs criteria:

- **Population**

Pregnant women over the age of 18 years, of all BMIs, but excluding studies of population groups with physical or mental health conditions that would preclude them from participating in a diet or physical activity-based intervention (e.g. women with eating disorders or GDM).

- **Interventions**

Digital interventions targeting dietary behaviours or physical activity in pregnancy, with the aim of improving diet and/or physical activity in pregnancy and/or managing GWG. Interventions aiming to increase GWG were excluded. Interventions had to be exclusively digital, using text messages, apps and/or websites. Initial in-person or telephone study briefing sessions were deemed acceptable, as they were felt to reflect real-world situations in which healthcare professionals might introduce an intervention to pregnant women as part of an antenatal care programme. Interventions using interpersonal coaching or support beyond this were excluded, as were digital interventions delivered in a healthcare setting (e.g. a clinic or hospital).

- **Comparators**

Comparators were either usual antenatal care, minimal interventions (i.e. information only rather than active behaviour change) or non-diet/physical activity interventions.

- **Outcomes**

The primary outcomes were GWG (measured as total gain in kgs and/or compliance with NAM GWG guidelines (Rasmussen & Yaktine, 2009), and/or changes in dietary behaviours and/or changes in levels of physical activity. The secondary outcome was engagement, measured by intervention attrition rates and usage of the intervention features. BCTs were coded according to the BCT Taxonomy (v1) (Michie et al., 2013).

- **Study Design**

Only randomised control trials and randomised pilot studies were included in this review.

4.3.3 Data extraction and data synthesis

Data extracted for the systematic review included author and date of publication, geographical region, study design, behaviours targeted and specific behavioural goals, sample size, participant information, technology used, intervention features, theory used, gestational week in which intervention started, length of intervention, nature of control, attrition rate, engagement levels, outcome measures and outcomes. A secondary and independent data extraction was completed by co-author Dr Helen Croker (HC). Two authors (AR and PC) independently coded the BCTs within each intervention according to the BCT Taxonomy (v1) (Michie et al., 2013). If available and required, study development papers and protocols were retrieved for this purpose. In most instances, authors were contacted for additional information. BCTs were coded only if there was unequivocal evidence of their existence (Michie et al., 2013). Disagreements were discussed to reach consensus.

4.3.4 Quality assessment

Risk of bias within studies was evaluated using the Cochrane Collaboration RoB 2.0 tool for assessing risk of bias (Sterne et al., 2019). This procedure was replicated independently by Dr Andrea Smith (AS), a co-author on this study. The five domains evaluated were: risk of bias arising from the randomization process; risk of bias due to deviations from the intended interventions; missing outcome data; risk of bias in measurement of the outcome and risk of bias in selection of the reported result. Bias was classified as being low risk, high risk or some concerns according to predetermined criteria set by RoB 2.0. Rating discrepancies between authors were resolved through discussion. Risk of bias across studies could not be evaluated due to the small number of studies included in the meta-analyses (Higgins et al., 2022).

4.3.5 Data analysis

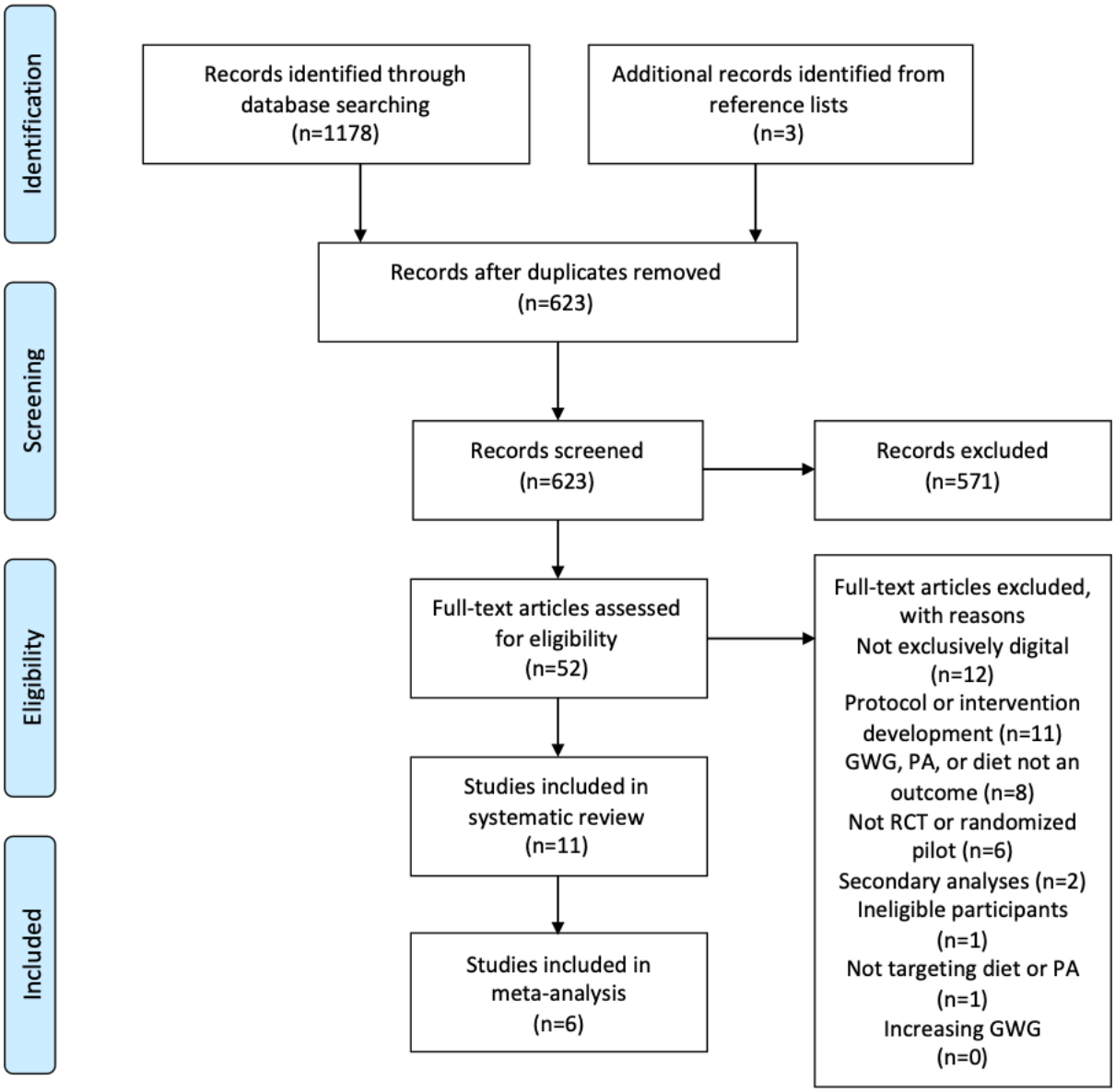
Given the substantial heterogeneity of reported outcome measures in the identified studies, data could only be quantitatively pooled for meta-analysis from studies measuring GWG. Separate analyses were conducted for intention to treat (ITT) data and per protocol (PP) data. Meta-analysis was used to determine the differences in mean total GWG (in kgs) from baseline to post-intervention using the inverse-variance method. The odds ratio was pooled using meta-analysis for studies reporting GWG as a dichotomous outcome (proportion of women exceeding NAM guidelines) using the Mantel–Haenszel method. The test for the overall pooled effect estimate was assessed using Z-statistics at $P < 0.05$. Heterogeneity between studies was evaluated using the Cochran Q (Chi^2 test) and the I^2 statistics in the RevMan software ("Review Manager Web (RevMan Web). Version 5," 2020). Pre-planned subgroup analyses were conducted comparing studies where BCTs could be identified in initial briefing sessions with those where none were apparent.

4.4 Results

Figure 4-1: Flow chart of study selection process shows the study selection process. Systematic searching of six literature databases identified 623 non-duplicate study records. After assessment of eligibility in accordance with the inclusion and exclusion

criteria, 11 eligible studies were identified, of which 6 studies were included in subsequent meta-analyses.

Figure 4-1: Flow chart of study selection process



4.4.1 Study characteristics

Table 4-1 summarises the characteristics of the 11 studies included in this review. All studies were published between 2012 and 2019. Of the 11 studies, seven were randomised pilot or feasibility studies (Choi, Lee, Vittinghoff, & Fukuoka, 2016; Dahl,

2018; Evans, Wallace, & Snider, 2012; Hayman et al., 2017; Pollak et al., 2014; Redman et al., 2017; Willcox et al., 2017) and four were RCTs (Evans et al., 2015; Huberty et al., 2017; Olson et al., 2018; Smith et al., 2016). Two of the four RCTs reported being adequately powered (Olson et al., 2018; Smith et al., 2016) whereas the other two reported being underpowered as a result of small starting sample (Huberty et al., 2017) or low follow-up rate (Evans et al., 2015). Nine studies took place in the USA (Choi et al., 2016; Dahl, 2018; Evans et al., 2015, 2012; Huberty et al., 2017; Olson et al., 2018; Pollak et al., 2014; Redman et al., 2017; Smith et al., 2016) and two in Australia (Hayman et al., 2017; Willcox et al., 2017). Sample sizes varied from n=35 to n=1689. Two studies (Evans et al., 2015, 2012) targeted diet only, four studies (Choi et al., 2016; Hayman et al., 2017; Huberty et al., 2017; Smith et al., 2016) targeted physical activity only and the remaining five (Dahl, 2018; Olson et al., 2018; Pollak et al., 2014; Redman et al., 2017; Willcox et al., 2017) targeted both diet and physical activity. Seven studies reported on only one outcome; GWG (n=2) (Olson et al., 2018; Redman et al., 2017), dietary (n=2) (Evans et al., 2015, 2012) or physical activity (Choi et al., 2016; Hayman et al., 2017; Huberty et al., 2017) (n=3) behaviours. The remaining four (Dahl, 2018; Pollak et al., 2014; Smith et al., 2016; Willcox et al., 2017) reported on GWG as well as change in diet and physical activity. Three studies focussed specifically on women with overweight or obesity (Pollak et al., 2014; Redman et al., 2017; Willcox et al., 2017) and three (Choi et al., 2016; Huberty et al., 2017; Smith et al., 2016) focussed on inactive or sedentary women. The duration of the interventions varied from 4 weeks (Hayman et al., 2017) to up to 32 weeks (Huberty et al., 2017).

Delivery method varied across the studies with four using text messaging (Evans et al., 2015, 2012; Huberty et al., 2017; Pollak et al., 2014), three using an app (Choi et al., 2016; Dahl, 2018; Redman et al., 2017), three being website-based (Hayman et al., 2017; Olson et al., 2018; Smith et al., 2016) and one combining text messaging with a website (Willcox et al., 2017). Seven studies included an interpersonal briefing session at the start of the study (Choi et al., 2016; Dahl, 2018; Evans et al., 2012; Huberty et al., 2017; Pollak et al., 2014; Smith et al., 2016; Willcox et al., 2017). Four of these (Dahl, 2018; Evans et al., 2012; Huberty et al., 2017; Pollak et al., 2014) were for screening and/or study measures only, but three (Choi et al., 2016; Smith et al., 2016; Willcox et al., 2017) included discussions with intervention participants about

the intervention features. In Smith et al's study intervention participants received an in-person tutorial on how to use the website and its features and practice tracking physical activity. In Willcox et al's study the researcher discussed with intervention participants their individual GWG targets, weight monitoring and asked them to set a physical activity or dietary goal. In Choi et al's study, intervention participants were given a 30 minute in-person session covered physical activity recommendations, goal setting, problem solving, social support and planning for lapses.

Table 4-1: Study characteristics

Study	Country	Sample size	Study design	Study duration	Technology used	Behaviours targeted	Outcome(s) measured	Participants
Evans et al, 2012	USA	90	Pilot	2-3 months	Text	Diet	Diet	Low income, under-served pregnant women
Pollak et al, 2014	USA	35	Pilot	11-20 weeks	Text	Diet Physical Activity	GWG Diet Physical Activity	BMI 25-40 Gestation 12-21 weeks
Evans et al, 2015	USA	996	RCT	8- 22 weeks	Text	Diet	Diet	Military women Gestation <14 weeks
Smith et al, 2016	USA	51	RCT	20-26 weeks	Website	Physical Activity	GWG Diet Physical Activity	Sedentary women Gestation 10-14 weeks
Choi et al, 2016	USA	30	Pilot	12 weeks	App	Physical Activity	Physical Activity	Physically inactive women Gestation 10-20 weeks
Willcox et al, 2017	Australia	91	Pilot	18-26 weeks	Text & Website	Diet Physical Activity	GWG Diet Physical Activity	BMI> 25 Gestation 10-17.6 weeks
Redman et al, 2017	USA	54	Pilot	22-26 weeks	App	Diet Physical Activity	GWG	BMI> 25 Gestation 10.4-13.6 weeks
Hayman et al, 2017	Australia	77	Pilot	4 weeks	Website	Physical Activity	Physical Activity	Gestation 10-20 weeks
Huberty et al, 2017	USA	80	RCT	Up to 32 weeks	Text	Physical Activity	Physical Activity	Not meeting PHYSICAL ACTIVITY recommendations Gestation 8-16 weeks
Olsen et al, 2018	USA	1689	RCT	Average 28 weeks	Website	Diet Physical Activity	GWG	BMI 18.5-35 Gestation<20 weeks
Dahl et al, 2019	USA	87	Pilot	12 weeks	App	Diet Physical activity	GWG	BMI ≥18.5 Gestation<20 weeks

4.4.2 Risk of bias

Table 4-2 summarises study quality assessment. Overall study quality was variable. Five studies were deemed to have an overall 'high risk' of bias, three had a 'low risk' of bias and three were classified as having 'some concerns'. High and some concerns scores in some studies related to the fact that participants and research staff were aware of allocation to the intervention or control group. This can be hard to disguise particularly if the behavioural intervention involves giving participants access to resources that are clearly additional to the standard care control. However, the potential effect of research staff's knowledge of the allocation on results might have been limited given the self-directed nature of these interventions and the objective measurement of outcomes in some instances. Missing outcome data, typically due to high levels of attrition, and potential bias from not accounting for this in measurement of the data, was another reason for high risk of bias scores in some studies.

Table 4-2: Risk of Bias summary (RoB 2.0)

Bias						
Study	**Randomization process**	**Deviations from intended interventions**	**Missing outcome data**	**Measurement of the outcome**	**Selection of the reported result**	**Overall**
Evans et al, 2012						
Pollak et al, 2014						
Evans et al, 2015						
Smith et al, 2016						
Choi et al, 2016						
Willcox et al, 2017						
Redman et al, 2017						

Study	Randomization process	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall
Hayman et al, 2017						
Huberty et al, 2017						
Olsen et al, 2018						
Dahl et al, 2019						

Key: Red = high risk of bias; Yellow = some concerns; Green = low risk of bias

4.4.3 Description of the interventions

Table 4-3 summarises the intervention features, attrition engagement and effectiveness, data. All interventions were theory-based, with Social Cognitive Theory (Bandura, 1999) being the most widely used (n=8). All trials started in the first or second trimester of pregnancy. Study duration varied considerably with one trial lasting 4 weeks (Hayman et al., 2017), two 12 weeks (Choi et al., 2016; Dahl, 2018), one 16 weeks (Pollak et al., 2014) and the remainder ≥20 weeks, completing at or close to term. Most studies compared the intervention with standard care (Evans et al., 2015, 2012; Pollak et al., 2014; Redman et al., 2017; Smith et al., 2016; Willcox et al., 2017) or access to information-only aspects of the intervention (Choi et al., 2016; Hayman et al., 2017; Huberty et al., 2017; Olson et al., 2018). In one study the control was an equivalently structured intervention targeting stress reduction (Dahl, 2018).

Table 4-3:Intervention features, engagement and effectiveness

Study	Behaviours targeted	Intervention features	Theory	Intervention group attrition	Engagement levels	Results
Evans et al, 2012	Diet	Text messages – approx. 3 per week	SCT; TM; HBM	30.1%*	NA	Ineffective No differences in fruit and vegetable consumption
Pollak et al, 2014	Diet Physical Activity	Tailored text messages; goal setting; weight and behaviour monitoring; feedback	SCT	39.1%	86% read and responded to texts about self-monitoring behavioural goals and GWG	Ineffective ITT: no differences in GWG PP: non-significant difference in GWG. No differences in diet or physical activity
Evans et al, 2015	Diet	Text messages – approx. 3 per week	SCT; TM; HBM	51.4%	NA	Ineffective No differences in fruit and vegetable consumption
Smith et al, 2016	Physical Activity	Control website plus goal setting, problem solving, journal, calendar, community forum	SCT	7.7%	NA	Ineffective No differences in GWG. Significantly greater physical activity and energy intake mid-pregnancy for intervention group, but no differences by end
Choi et al, 2016	Physical Activity	Fitbit, app with daily messages, tips, problem solving techniques, modelling, activity diary, feedback and self-monitoring	SCT	6.7%	Week 1:76% and 81% response to daily messages and activity diary Week 12: 50% and 40%	Ineffective Non-significant increase in daily steps and lower perceived barrier to being active for intervention group
Willcox et al, 2017	Diet Physical Activity	Tailored text messages, video messages, chat room interaction, goal setting, weight monitoring (multiple modalities)	SCT	10%	98% read all or most texts; 96% replied; 95% set goals; 83% self-monitored GWG; 31% joined social media; 0.87 average per month website visits	Effective Significantly lower GWG and less likely to reduce total physical activity in intervention group. No difference in % exceeding GWG guidelines or dietary behaviour

Study	Behaviours targeted	Intervention features	Theory	Intervention group attrition	Engagement levels	Results
Redman et al, 2017	Diet Physical Activity	Weekly/biweekly app-based coaching on diet, physical activity and weight, daily self-monitoring of diet, steps and weight	Non-specific	0%	71% submitting weight and 73% steps data	Effective Significantly lower % exceeding GWG guidelines and average GWG non-significantly lower in intervention group
Hayman et al, 2017	Physical Activity	Four weekly modules: action planning tool; feedback messages	SCT	30.8%	99% completion of weekly modules; 72% goal setting and action planning tasks	Effective Significant positive difference in moderate to vigorous physical activity in intervention group
Huberty et al, 2017	Physical Activity	Physical activity specific texts	SCT; TM; HBM	5.9%*	NA	Ineffective No differences in physical activity
Olsen et al, 2018	Diet Physical Activity	Control website plus weight gain tracker, diet and physical activity goal setting, self-monitoring, blogging tool	IMBP; BMPD	2.5%	46.1% logged in once every 45 days; median log in rate was 5.6% of days= 10 times; median page views 6 for BCT pages;	Ineffective No differences in total GWG or % exceeding GWG guidelines
Dahl et al, 2019	Diet Physical activity	12 weekly behaviour change challenges via Make-me app; virtual teams; website with weight gain tracker and information	UTAUT	38.9%	NA	Ineffective Non-significant higher % within GWG guidelines and significant positive effect on healthy eating behaviours or physical activity for intervention group

Note and abbreviations:

* Attrition rate across intervention and control group

SCT: Social Cognitive Theory (Bandura, 1999)

TM: Transtheoretical Model (Prochaska & Velicer, 1997)

HBM: Health Belief Model (Janz & Becker, 1984)

IMBP: Integrative Model of Behavior Prediction (Fishbein & Yzer, 2003)

BMPD: Behavior Model for Persuasive Design (Fogg, 2002)

UTAUT: Unified Theory of Acceptance and Use of Technology (Venkatesh, 2003)

4.4.4 Effectiveness of the interventions

Whilst all studies reported on intervention effectiveness, it should be noted that seven of the studies were pilot studies and not powered to provide statistically valid evidence of intervention effectiveness. As such the following findings should be viewed as indicative rather than clear evidence of intervention effectiveness or ineffectiveness.

Of the 11 studies, three reported significant positive effects of their interventions in comparison to control groups; two on GWG (Redman et al., 2017; Willcox et al., 2017) and two on physical activity (Hayman et al., 2017; Willcox et al., 2017).

The six studies with GWG as the primary outcome, varied in their measurement of total GWG. Three studies used the difference between last measured weight before delivery (34-37 weeks) and baseline weight (10-17 weeks) (Olson et al., 2018; Redman et al., 2017; Willcox et al., 2017). Two studies (Dahl, 2018; Smith et al., 2016) used self-reported pre-pregnancy weight as the starting weight and one study (Pollak et al., 2014) used a model of estimated mean weights at 16 and 40 weeks. One study showed significantly lower total GWG amongst intervention participants (Willcox et al., 2017), while another showed significantly fewer intervention participants exceeding NAM guidelines (Redman et al., 2017). The remaining studies (Dahl, 2018; Olson et al., 2018; Pollak et al., 2014; Smith et al., 2016) showed no significant difference between intervention and control groups on any GWG measures. A meta-analysis conducted on ITT data (n=3) showed a lower total GWG in the intervention group, although the mean difference of -0.28kgs was non-significant (95% CI: -1.43, 0.87) using the inverse variance method and a fixed effect model (I^2 = 0%, P = 0.38) (see Figure 4-2). Similarly, for PP data (n=4), total GWG was lower in the intervention group, although the mean difference of -0.65kgs was non-significant (95% CI: -1.98, 0.67) (I^2 = 53%, P = 0.10) (see Figure 4-3). The subgroup analyses revealed no significant change to this result (see Appendix 2). A meta-analysis of studies reporting PP percentages exceeding NAM guidelines showed no effect of interventions relative to comparators (OR: 1.02, 95%CI: 0.82, 1.27) (I^2 = 45%, P = 0.) (See Figure 4-4).

Figure 4-2: Pooled analysis of digital interventions on total GWG (kgs) – intention to treat studies

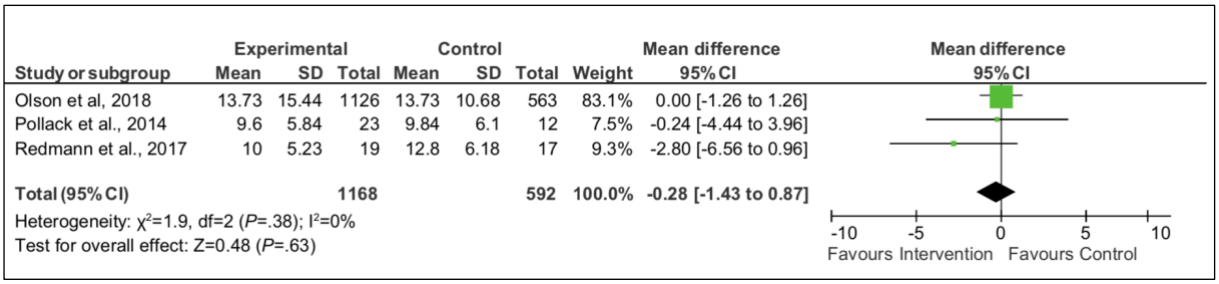


Figure 4-3: Pooled analysis of digital interventions on total GWG (kgs) – per protocol studies

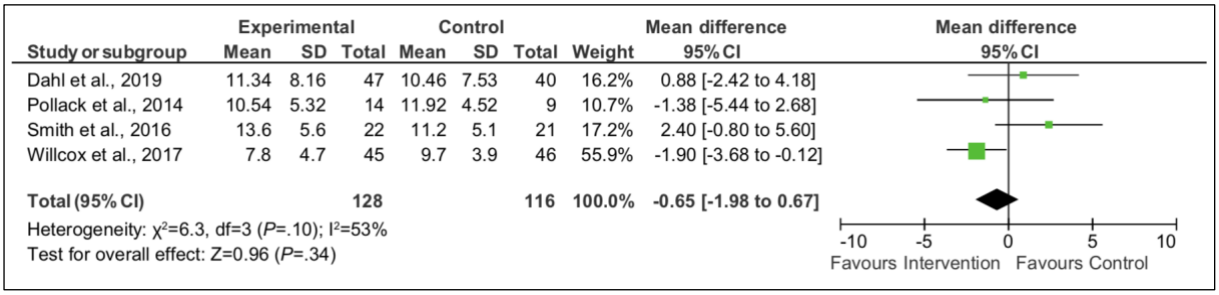
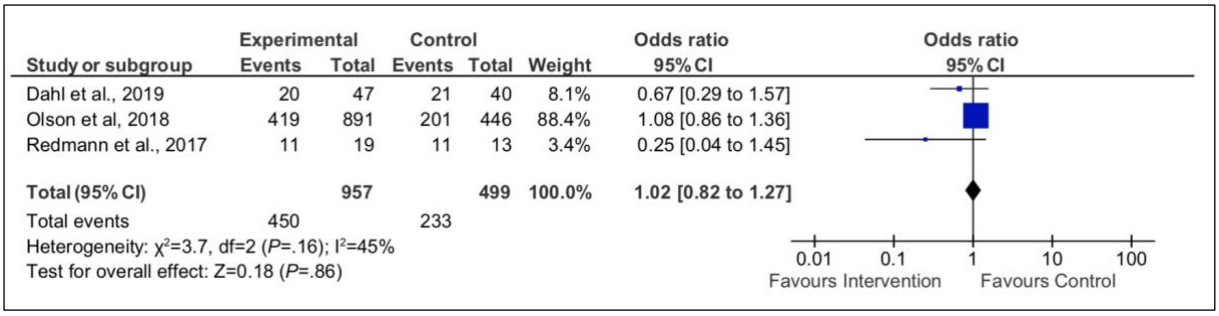


Figure 4-4: Pooled analysis of digital interventions on percentage of women exceeding NAM guidelines – per protocol studies



Of the seven studies reporting physical activity, three showed significant positive effects of the intervention on levels of physical activity (Hayman et al., 2017; Smith et al., 2016; Willcox et al., 2017). Of these three, one study relied on self-reported physical activity and showed significantly smaller reductions in total, light and moderate intensity physical activity in the intervention group compared to the control group (Willcox et al., 2017). The other two studies used smart technology to provide an objective measure physical activity (Fitbit (Hayman et al., 2017) and SenseWear

Mini Arm Band (Smith et al., 2016)). One study reported a significant increase in moderate to vigorous physical activity for the intervention group compared to the control group, albeit over a four week period only (Hayman et al., 2017). The other study reported significantly greater levels of sustained physical activity for intervention participants compared to control participants in mid-pregnancy, but the effect had disappeared by the end of the intervention (Smith et al., 2016). Only one of the six studies reporting on dietary behaviours was effective in improving diet (Dahl, 2018). Using a self-report measure (the Rapid Eating and Activity Assessment for Participants Short Scale), intervention participants in this study scored significantly higher on healthy eating practices (measuring meal behaviours such as skipping breakfast and serving frequencies, such as how often do you drink less than 2 servings of milk, yogurt, or cheese a day) compared to the control participants.

4.4.5 Behaviour Change Techniques

A summary of the 23 different BCTs identified within the interventions can be found in Appendix 3. Only one study specified all of the included BCTs (Willcox et al., 2017) and this study reported the highest number of BCTs (n=17). In two interventions only one BCT was evident (Evans et al., 2015, 2012). In the remaining interventions the number of BCTs ranged from 5 to 15 BCTs. The three effective interventions used on average twice the number of BCTs than other interventions (mean: 14 vs. 7). *Information about health consequences* was the only BCT to be used in all interventions. Beyond this, *goal setting (behaviour)* appeared in eight interventions and *problem solving* and *self-monitoring (behaviour and outcome)* in seven interventions. Seven BCTs were common to the three interventions showing a significant effect (Hayman et al., 2017; Redman et al., 2017; Willcox et al., 2017). These were *goal setting (behaviour), problem solving, review of behaviour goals, feedback on behaviour, social support, information about health consequences* and *information about emotional consequences*. *Review of behaviour goal* was the only BCT used exclusively in the three effective interventions. The three information-only interventions that included no active or interactive BCTs such as goal setting, self-monitoring, problem solving or feedback, were all ineffective (Evans et al., 2015, 2012; Huberty et al., 2017)

4.4.6 Engagement with interventions

Attrition rates were reported by all the studies, although two studies (Evans et al., 2012; Huberty et al., 2017) only provided figures for all participants rather than separating out intervention and control participants (See Table 4-3). Six studies reported intervention attrition rates of 10% or less (Choi et al., 2016; Huberty et al., 2017; Olson et al., 2018; Redman et al., 2017; Smith et al., 2016; Willcox et al., 2017). These studies identified reasons for dropping out of the intervention, distinguishing between medical and study-related reasons. Three of these studies (Huberty et al., 2017; Redman et al., 2017; Willcox et al., 2017) incentivised participants, and two (Choi et al., 2016; Smith et al., 2016) introduced an element of self-selection by recruiting women who were motivated or willing to increase their physical activity. In the remaining five studies intervention attrition was over 30% and lost to follow up reasons were not explained beyond being unable to contact through moving.

Six studies (Choi et al., 2016; Hayman et al., 2017; Olson et al., 2018; Pollak et al., 2014; Redman et al., 2017; Willcox et al., 2017) reported on intervention engagement levels using a variety of measures including usage of self-monitoring, goal setting, action planning and social media features, response to texts, completion of tasks and website log-ins (See Table 4-3). Four studies (Hayman et al., 2017; Olson et al., 2018; Pollak et al., 2014; Willcox et al., 2017) evaluated participants' views of the intervention although only one (Hayman et al., 2017) explored user experience of the technology. Four studies (Hayman et al., 2017; Pollak et al., 2014; Redman et al., 2017; Willcox et al., 2017) reported engagement levels in excess of 70%, including the three interventions with significant effects (Hayman et al., 2017; Redman et al., 2017; Willcox et al., 2017). A further study (Choi et al., 2016) started with a similarly high level of engagement although it fell to below 50% over the course of the 12 week intervention. The final study (Olson et al., 2018) reported engagement levels of 46%. Five studies (Choi et al., 2016; Hayman et al., 2017; Pollak et al., 2014; Redman et al., 2017; Willcox et al., 2017) integrated interactive elements to encourage engagement with the intervention. Two interventions (Pollak et al., 2014; Willcox et al., 2017) sent 4+ text messages per week encouraging self-monitoring and giving tailored feedback, and three (Choi et al., 2016; Hayman et al., 2017; Redman et al., 2017) used in-app messaging to provide tailored feedback.

4.5 Discussion

The aim of this systematic review and meta-analysis was to determine the effectiveness of diet and physical activity interventions during pregnancy delivered using exclusively digital technology, and to provide insight into how BCTs and engagement with intervention features might be driving effectiveness. A total of 11 studies were identified, all of which were published from 2012 onward, with 6 studies published in 2017 and 2018. App and mobile-accessible website interventions appeared only since 2017, reflecting the emergent nature of mobile health interventions to encourage healthy behaviors during pregnancy. Meta-analyses showed no significant benefit of exclusively digital interventions on total GWG. Substantial heterogeneity in measures of change in dietary behaviors and physical activity precluded further meta-analyses. BCT coding identified seven BCTs that were common to all effective interventions. Effective interventions averaged over twice as many BCTs from the *goals and planning* and *feedback and monitoring* domains as ineffective interventions. Six studies reported on user engagement and their data indicated a positive association between high engagement with key BCTs and greater intervention effectiveness. Interventions using proactive messaging, such as reminding participants to engage in BCTs and/or providing feedback or tips, appeared to have higher levels of engagement.

4.5.1 Effectiveness

Meta-analyses of the digital interventions measuring GWG showed no effect on the total GWG or weight gain within the NAM guidelines. Although the majority of these studies were pilot RCTs and insufficiently powered to detect an effect, these findings indicate that exclusively digital interventions to manage GWG may be less effective than those using interpersonal delivery. Lack of consistency in reported outcome measures precluded meta-analyses of the effects of digital interventions on dietary behaviors and physical activity. Only three of the seven studies measuring changes in physical activity reported significant effects of the intervention, suggesting that for physical activity interventions during pregnancy, digital delivery may similarly be less effective than interpersonal delivery (Chan et al., 2019).

The 11 interventions varied considerably in terms of not only the targeted behaviors but also the technologies, functionalities, and BCTs used, in part reflecting the rapidly evolving nature of digital interventions. As such, it would be premature to conclude that exclusively digital delivery methods *per se* are less effective than interpersonal delivery methods for behaviour change interventions during pregnancy. Indeed, Redman et al. (2017) made a direct comparison of digital delivery and in-person delivery of the same intervention in their study. They found the intervention to be effective via both delivery methods, with digital delivery showing greater adherence and lower costs (for both participants and clinics) compared with in-person delivery.

4.5.2 BCTs

This systematic review aimed to identify the BCTs associated with effective interventions. The number of identifiable BCTs ranged from one to 17 within a single intervention, with the two most effective interventions (Redman et al., 2017; Willcox et al., 2017) using the highest number (n=17 and n=15). The average number of BCTs was nine compared with approximately five reported in two earlier systematic reviews of lifestyle interventions targeting pregnant women (Gardner et al., 2011; Hill et al., 2013). It is unclear whether this increase reflects a trend toward greater intervention complexity, or the opportunity digital interventions afford to include more components or is simply a matter of improved reporting of BCTs. Consistent with a previous systematic review, this review found that effective interventions tended to report a greater number of BCTs (Hill et al., 2013). A meta-analysis of 122 physical activity and healthy eating interventions (for all adults) showed effectiveness to be a function of not simply the number of BCTs but particular BCTs—*self-monitoring* and at least one other of four techniques derived from control theory, *prompt intention formation, prompt specific goal setting, provide feedback on performance, prompt self-monitoring of behavior,* and *prompt review of behavioural goals* (Michie et al., 2009). In Mair et al.'s (2023) umbrella review of the most effective BCTs used in digital health interventions (n=61) strong evidence was found for the effectiveness of the following BCTs: *education, communication with a professional, tailored reminders, goals and planning, feedback and monitoring, and personalization components* (Mair et al., 2023). A recent systematic review (n=10) of BCTs used in interventions to promote physical activity in pregnancy identified *problem solving*, *social support, graded tasks,*

goal setting (behaviour), instruction on how to perform a behaviour, self-monitoring of behaviour, demonstration of the behaviour, and action planning as promising BCTs (Ma, Chau, Liang, & Choi, 2023). The three effective interventions did however average over twice as many *goals and planning* and *feedback and monitoring* BCTs as ineffective interventions (mean (SD) 7.6 (2.1) and 3.4 (2.9), respectively).

There was considerable variation in the execution and delivery of BCTs. For example, in some studies, participants were invited to set a single goal, whereas in others, they were able to set multiple goals. In some instances, participants were encouraged to choose their own goal, whereas in others, the goal was prescribed. Similarly, some interventions required participants to submit self-monitoring data regularly (behavioural and goal related), whereas others recommended and provided functionality for self-monitoring but did not make it obligatory. Four studies proactively messaged participants to remind them to self-monitor (Choi et al., 2016; Dahl, 2018; Pollak et al., 2014; Willcox et al., 2017), whereas one messaged participants only if they failed to self-monitor (Redman et al., 2017). In three of the studies that incorporated an initial in-person session for intervention participants (Choi et al., 2016; Smith et al., 2016; Willcox et al., 2017) one or more BCTs were identifiable at this stage, raising the question as to whether the content of these sessions contained sufficient BCTs in their own right to bring about a change. The influence of these variations in the context, execution, and delivery of BCTs on intervention effectiveness could not be quantified by the methods used in this study. Given the interactive and dynamic nature of digital interventions, additional measures may be needed to capture the impact of features, such as the timing of delivery and degree of individual tailoring of BCTs.

In this review, *information about health consequences* was the most widely used BCT, which featured in all interventions. *Goal setting (behavior)* was the next most widely used BCT, appearing in all but the three text message-only interventions. *Problem solving, self-monitoring of behavior, self-monitoring of outcomes,* and *instructions on how to perform a behavior* all appeared in seven interventions. *Feedback on behavior* was provided in six interventions, including the three reporting significant effects of the interventions (Hayman et al., 2017; Redman et al., 2017; Willcox et al., 2017). The BCT *review behavior goal* was only present in these three effective interventions,

suggesting that this may be a critical active ingredient in these digital interventions. It is possible that *review behavior goal* in combination with *self-monitoring of behavior* and *feedback on behavior* work together to support the self-regulation of dietary and physical activity behaviors during pregnancy. Consistent with this hypothesis, a meta-analysis and meta regression of BCTs in weight gain prevention interventions in general population adults showed *feedback on behaviour* (and also *graded tasks*) to be significantly associated with less weight gain, whilst *review behaviour goals* was significantly associated with lower energy intake (Awoke et al., 2022).

Social support was present in six out of the 11 interventions, which included the three effective interventions. Once again, the execution of *social support* varied, ranging from advice on how to seek support to online group forums for participants. There is no consensus on whether social support or interaction with other participants improves intervention effectiveness, and no clear pattern emerged from this review (Chan & Chen, 2019; Morrison, 2015; Walker et al., 2018). More research is needed to understand the type of social support that is most beneficial to digital interventions encouraging healthy behaviors during pregnancy.

Insufficient description of intervention components, coupled with a lack of systematic recording of BCTs, compromised the quality of the BCT analysis. Only one study provided details of all the BCTs used in the intervention, whereas the presence of BCTs had to be inferred from descriptions of the interventions in all other studies (Willcox et al., 2017). This raises the possibility that there may be additional but unreported BCTs in other studies. Previous studies that have coded BCTs used in gestational weight management trials have called for greater clarity and accuracy in the reporting of BCTs (Soltani et al., 2016). Without systematic reporting of active intervention ingredients, it is difficult to precisely determine which BCTs may be driving effectiveness.

4.5.3 Engagement

Six studies provided measures of user engagement (Choi et al., 2016; Huberty et al., 2017; Olson et al., 2018; Redman et al., 2017; Smith et al., 2016; Willcox et al., 2017). These varied considerably, including the number of replies to texts, frequency of

inputting weight monitoring data and logging onto and viewing web pages. Only one study (Hayman et al., 2017) provided feedback on user experience. Given the importance of user engagement to the success or otherwise of self-managed digital interventions, more detailed and standardized measures could facilitate better evaluation and cross-study comparison (Perski, Blandford, West, & Michie, 2017). Perski et al proposed more comprehensive measures, including both the extent (i.e., amount, frequency, duration, depth) of usage and the user experience (Perski, Blandford, et al., 2019). Reinforcing the need for a more holistic evaluation of engagement, Yardley et al proposed identifying and reporting on *effective engagement* rather than simply higher levels of engagement, where effective engagement is defined as "sufficient engagement with the intervention to achieve the intended outcome" (Yardley et al., 2016). The combination of web analytics and survey feedback clearly offers the opportunity to develop specific and relevant indices of engagement (Taki et al., 2017).

The three effective interventions all reported engagement levels >70% with key BCTs (*goal setting* (Hayman et al., 2017; Willcox et al., 2017), *self-monitoring* (Redman et al., 2017; Willcox et al., 2017) and *action planning* (Hayman et al., 2017)). Conversely, the study with the lowest engagement level, where only 46% of participants logged onto the website at least once every 45 days, and the use of *goal setting* and *self-monitoring* features was 35% and 23% of the participants, respectively, reported no effect of the intervention (Olson et al., 2018). These findings suggest that ineffectiveness may be partially a function of poor engagement with key BCTs rather than poorly designed interventions *per se*. Supporting this hypothesis, this study with low levels of engagement conducted secondary analyses investigating whether usage patterns of the intervention features reduced the risk of excessive GWG and found frequent usage patterns were associated with lower total GWG (Graham, Strawderman, Demment, & Olson, 2017; Olson, Strawderman, & Graham, 2019). In addition, the use of the dietary tool (*goal setting* and *self-monitoring*) was associated with improved GWG management for women with healthy BMI, although not for those with high BMI.

One consistent feature of the interventions reporting the levels of engagement over 70% was regular in-app messaging or text messaging giving encouragement,

reminders to self-monitor, or tailored feedback on progress. Prompts and reminders have been shown to promote engagement in digital interventions (Alkhaldi et al., 2016). Similarly, tailoring messages to the characteristics and usage patterns of the individual has been shown to improve adherence (Bidargaddi, Pituch, Maaieh, Short, & Strecher, 2018). Notably, the Olsen et al. study in which participants were sent a generic weekly email reported particularly low levels of engagement. The frequency and timing of these messages are also important (Muench & Baumel, 2017). The Wilcox et al intervention where participants received 4 to 5 texts per week found that 79% of participants thought the frequency of messages was *about right*, although 21% thought it was *too high*. Huberty et al investigated the dose and timing of messages to promote physical activity by comparing 3 texts per week with daily texts and found daily texts to be less effective, indicating that too much messaging can be counterproductive. None of the studies referred to the use of gamification techniques to promote engagement, although elements of some of the interventions could potentially be classified as gamification, such as team challenges in Dahl et al's intervention (Hamari, Koivisto, & Sarsa, 2014). Incorporating gamification features, such as badges and challenges, has been shown to increase regular engagement and immersion in digital health interventions (Cugelman, 2013; Sardi, Idri, & Fernández-Alemán, 2017).

The final issue regarding engagement concerns who the interventions are reaching. Only one study reported (in follow-up analyses) on high versus low engagers, revealing significant differences according to ethnicity and demographics, with high engagers being more likely to be higher income, white, older and married (Graham et al., 2017). Often, it is those who would benefit most from behaviour change who are least likely to engage in behaviour change interventions (Dalton et al., 2018). Greater insight into who engages with the interventions could enhance learnings from these studies and help to ensure that digital intervention designs are accessible to all, including those with low digital health literacy (Busse et al., 2022).

4.5.4 Strengths and limitations

A strength of this systematic review is that it is the first to focus on exclusively digital interventions to promote healthy dietary behaviors, physical activity, or weight

management during pregnancy. In addition to evaluating their effectiveness, this review conducted a rigorous assessment of BCTs and participant engagement to provide insight into what may be driving effectiveness - a crucial step if the cost and reach advantages of digital interventions are to be leveraged. However, the extent to which the analysis of BCTs and techniques to enhance engagement can identify predictors of intervention effectiveness are limited given the heterogeneity of the intervention designs, the participant groups and the construction of the BCTs. There are several additional limitations to this systematic review. First, most of the studies included were pilot studies or RCTs with small sample sizes. In their meta-epidemiological study of the influence of pilot and small trials in meta-analyses of behavioural interventions, Beets et al showed the unreliability of effect sizes reported in pilot and small trials versus large RCTs (Beets et al., 2023). Accordingly, the results of these meta-analyses should be interpreted with caution. Second, the risk of bias across the studies was moderate to high, with 5 studies scoring overall *high* and a further 3 scoring as *some concerns*, as assessed by RoB 2.0. Once again, this means that the results of the meta-analyses should be treated with caution. Third, the timing of the interventions within pregnancy varied both in terms of the start point within the gestational window and duration of the intervention, meaning the effect on GWG was not strictly comparable across the studies. This, coupled with inconsistent measures of GWG and, in some cases, reliance on self-reported weight measures should be considered when appraising the findings. Finally, limited reporting of intervention features meant that not all BCTs were recorded. Providing more detailed descriptions of the interventions' design and content (in supplementary files) would augment shared learnings from these studies. Similarly, more detailed and consistent engagement measures would have enhanced the interpretation of user engagement data.

4.5.5 Conclusions

The present meta-analyses show that exclusively digital interventions targeting dietary behaviors, physical activity, and weight management during pregnancy have no impact on GWG, meaning that the current exclusively digital interventions are less effective than interpersonal interventions in this field. There was considerable variation in intervention effectiveness across the 11 studies, with three studies from 2017

reporting significantly positive effects of their interventions. Limited data precluded confident identification of the ingredients of successful interventions, although this review suggests that variation in effectiveness might be partially explained by the BCTs used and levels of interactivity to encourage engagement with the intervention features. Effective interventions used more BCTs (particularly BCTs from *goals and planning* and *feedback and monitoring* domains) and reported higher levels of engagement with key BCTs. Effective interventions also used interactivity, in the form of messages of encouragement, personalized feedback, and prompts to remind participants to use key BCTs, such as *goal setting* and *self-monitoring,* to promote engagement.

There are several compelling reasons for considering using digital interventions to promote healthy dietary and physical activity behaviors during pregnancy: smartphone ownership is over 98% among women of childbearing age (Statista, 2022) and usage of pregnancy apps is pervasive (Hughson, Daly, Woodward-Kron, Hajek, & Story, 2018); digital interventions have broader geographical reach and lower costs than interpersonal interventions (Iribarren, Cato, Falzon, & Stone, 2017; Redman et al., 2017) and apps have the potential to reach those who are less likely to engage with traditional antenatal healthcare (Eppes et al., 2023; Hughson et al., 2018). Meanwhile, midwives frequently report that they have neither the time nor expertise to advise pregnant women on physical activity and healthy eating (De Vivo & Mills, 2019). Future research needs to consider how to seize the opportunities presented by new technologies to enhance interactivity, improve user engagement, and bring greater effectiveness to these digital interventions.

4.5.6 Additional studies since publication of this review

Since this study was published (July 2020), several further studies have been published (identified through Google Scholar Alerts and checking this review's citings) as summarized below.

In Sweden, an RCT (n=305) compared the use of an app-based intervention (HealthyMoms) targeting diet, physical activity and weight gain in pregnancy with standard care (Sandborg et al., 2021). The app was trialed by women of all BMIs over

a six-month period. Although no differences in GWG between the intervention and control group were reported, the authors found in completers-only analysis, women with pre-pregnancy overweight or obesity had lower GWG in the intervention group than in the control group (–1.67 kg; 95% CI: –3.26, –0.09; *P*=.031, n=271). The results of a Bayesian estimation on this interaction model showed a 99% probability of any intervention effect on women with overweight or obesity and 81% probability that this effect was over 1 kg. In addition, intervention participants had significantly higher scores (equating to better diet quality) on the Swedish Healthy Eating Index at follow-up than the control group.

A Finnish study compared the use of a standard health app that allows users to track their diet and physical activity, with an enhanced app that included information on weight gain, diet quality and physical activity in pregnancy. No differences were found in GWG or dietary and physical activity behaviours between the standard health app users and the enhanced health app users, although given that the standard app was also promoting healthy behaviours the lack of difference cannot be taken as an indication of intervention ineffectiveness (Koivuniemi, Raats, Ollila, Löyttyniemi, & Laitinen, 2022). The authors noted that a significantly greater proportion of intervention participants tried to improve their eating habits. Interestingly the study investigated who was using the app and found that compared to occasional or non app users, frequent users were more educated, more likely to be underweight or healthy weight, have a better diet quality and be non-smokers, suggesting that this intervention was not reaching those who might benefit the most from it. This is a common concern with digital health interventions.

Redman et al's SmartMoms intervention, included in this review, has since been adapted for the Canada population. A small pilot study (n=29) investigated the effect of short-term usage of the app on GWG, diet, physical activity and sleep, comparing the outcomes of 'higher app users' with 'lower app users' (Souza et al., 2022). The authors reported a moderate effect size (28.6% vs. 15.4%; Cramer's V = 0.212) of app usage on rate of GWG, but no effect on other outcomes. A more comprehensive feasibility trial is underway (Adamo et al., 2022).

A small-scale Indonesian study (n=112) investigated the effectiveness of a food tracking app on dietary behaviours and weight gain in pregnancy using an RCT design (Koeryaman, Pallikadavath, Ryder, & Kandala, 2023). The authors reported a higher mean dietary diversity score for intervention group than for the control group (adjusted mean difference 0.77, 95% CI:0.28, 1.25; d=0.28; P=.005), but no significant difference in weight at the 12-week follow-up.

Collectively, these additional studies provide further evidence of the challenge of identifying what elements contribute to the effectiveness of interventions addressing diet, physical activity and weight gain in pregnancy, given the substantial heterogeneity in intervention design, target behaviours and health outcomes measured.

Chapter 5 Study 2a: A qualitative study investigating partner involvement in pregnancy and assessing interest in a digital behavioural intervention for pregnant women and their partners[3]

This chapter reports on the first part of the findings of Study 2, a qualitative study comprising online focus groups and telephone interviews with expectant parents and parents of a baby of up to 18 months old. The idea to explore the inclusion of partners in the intervention arose from Study 1 findings relating to the potential role of social support in intervention effectiveness. In order to determine how partners may be enrolled in the role of social support, I needed to understand the role and influence of the partner on a pregnant woman's dietary and physical activity behaviours and to determine barriers and facilitators to participating as a couple in the intervention. The findings from this part of Study 2 confirmed the potential of optional inclusion of partners in the intervention and helped me to design the messaging for partners.

5.1 Introduction

The results from Study 1 suggested that the BCT social support may play a role in intervention effectiveness (see 4.5.2). Social support (BCT 3.1,) is defined as "Advise on, arrange or provide social support (*e.g. from friends, relatives, colleagues,' buddies' or staff*) or non-contingent praise or reward for performance of the behaviour. It includes encouragement and counselling, but only when it is directed at the behaviour". It featured in six of the 11 interventions, including the three effective interventions, identified in the systematic review described in the previous chapter. However, in none of the identified interventions were participants' partners engaged or suggested in the role of social support. Indeed, pregnant women's partners very seldom feature in antenatal dietary, physical activity and weight management interventions. Given that partner support in pregnancy is associated with better

[3] A version of Study 2a has been published in BMC Pregnancy and Childbirth. Rhodes, A., Smith, A.D., Llewellyn, C.H. *et al.* Investigating partner involvement in pregnancy and identifying barriers and facilitators to participating as a couple in a digital healthy eating and physical activity intervention. *BMC Pregnancy Childbirth* **21**, 450 (2021).

outcomes (see 5.1.1), I decided to explore the potential of engaging couples in the intervention I was developing.

5.1.1 Partner support in pregnancy

Although studies are sparce and inconsistent in terms of how they measure partner involvement, overall, partner support in pregnancy appears to be associated with better health behaviours and health outcomes for mother and baby, as illustrated by the studies below.

In their analysis of a 2010 survey of new mothers in England (n=4616) Redshaw and Henderson found partner involvement to be associated with women's health-related decision making and behaviour during the perinatal period (Redshaw & Henderson, 2013). Partner involvement was assessed via a survey to mothers and defined by a partner's presence or absence at key events during the pregnancy as well as involvement in other pregnancy-related information gathering and decision-making. Their analysis showed that greater partner involvement was positively associated with greater adherence to antenatal healthcare (first contact with HCPs before 12 weeks' gestation, having a dating scan, number of antenatal checks and attendance at antenatal classes). This study excluded women not living with their husband or baby's father at the time of the survey and same sex couples. The authors did not give a reason for these exclusions but acknowledged that non-resident partners can also provide support.

A further cross-sectional study of women from diverse socioeconomic and ethnic backgrounds (n=2641), reported that receiving less or no partner support to be associated with higher levels of anxiety, depression and smoking in pregnancy (Cheng et al., 2016). In this study, partner support was measured by women's agreement (on a 4-point Likert scale) with 5 statements about the support they received from their partner that had been previously validated (Turner, Grindstaff, & Philips, 1990). Women without partners were scored as having no support, although the authors noted that removing this group from the analysis had no significant effect on the results.

Alio et al (2010) used the Florida birth records between 1998 and 2005 (n= 1,397,801) to compare birth outcomes of women listing a father's name on the birth certificate with those with no father's name (Alio, Kornosky, Mbah, Marty, & Salihu, 2010). Mothers in the 'fathers-absent' group had a higher level of obsetric complications (anemia, eclampsia and placental abruption) and a significantly lower mean birth weight (Mean (SD) = 3.169g (639.3) versus 3.333 g (559.7), $P < 0.01$). Whilst presence of a father's name on a birth certificate is not evidence of partner support, these findings are consistent with a literature review of studies exploring fathers' involvement in pregnancy and childbirth (Plantin, Olukoya, & Ny. 2011). This review pointed to evidence of partner and family support being related to foetal growth, infant mortality and ease of labour. The authors concluded that fathers' involvement can positively influence health and relationship outcomes for fathers, mothers and babies.

Studies have consistently reported levels of partner support varying according to ethnicity and wealth, with higher support typically being found amongst more affluent, non-black women (Alio et al., 2010; Cheng et al., 2016; Redshaw & Henderson, 2013).

A small qualitative study in Sweden of first time partners (n=14) concluded that the provision of professional support to both expectant parents can play a role in enabling partner support, by increasing couples' ability to communicate and experience togetherness (Bäckström et al., 2017). However expectant partners do not always receive support from HCPs. A meta synthesis of 13 qualitative studies reported that feeling excluded from the antenatal care process is an often-voiced view of partners, the consequence of which could be a key missed opportunity to engage partner support (Kowlessar, Fox, & Wittkowski, 2015). Further evidence for the importance of engaging partners comes from an integrative literature review of 31 studies and articles about fathers' involvement in pregnancy and childbirth which identified lack of informational support for fathers as a barrier to providing effective support for their pregnant partners (Xue, Shorey, Wang, & He, 2018).

As these studies show, measuring the effect of partner support on pregnancy outcomes is challenging and there is little consistency in approach, in particular the way in which partner support is defined and whether an objective measure of support is used or the measure is based on the views of one or both partners. However, the

limited evidence points to a positive effect of partner support as well as the desire of partners to be involved.

Even less is known about partners' role in supporting pregnant women's healthy dietary and physical activity behaviours. In one qualitative study of 22 pregnant women with overweight or obesity, women reported finding it easier to be active in pregnancy with the support of their partner (Flannery et al., 2018). A study of 152 couples exploring associations between partner support and physical activity and dietary behaviours found a positive effect of perceived partner support on women's physical activity (estimate = 0.34, SE = 0.17, p = 0.04) but not on their dietary behaviours (Versele et al., 2022).

Other qualitative studies investigating partners' effect on women's dietary behaviours in pregnancy paint a more complex picture, with reports of partners being supportive and encouraging but also criticising and monitoring women's behaviours and weight gain (Flannery et al., 2020; Montgomery et al., 2012). Comments from Flannery et al.'s (2020) qualitative interviews with 30 women include descriptions of partners controlling women's diets in ways that were neither appreciated by the women nor necessarily healthy. Montgomery et al. (2012) asked 16 men about their views on their partner's GWG and revealed a discordance between experiencing negative perceptions of and feelings about GWG and trying to be a supportive partner.

In spite of evidence of couples' concordance in health behaviours and health behaviour change, to date few interventions encouraging healthy eating, physical activity and/or weight management in pregnancy have included partners (Arden-Close & McGrath, 2017). Indeed, to date fathers have been under-represented in perinatal interventions in general. In their systematic review of perinatal digital interventions targeting fathers Xie et al found only 29 intervention studies (search up to June 2022). These interventions covered a broad range of outcomes, with parenting knowledge, attitudes and confidence and parental mental health featuring frequently. Importantly, in only a third of cases were fathers involved in co-designing the intervention.

There are two notable dietary interventions in pregnancy that have included partners. The first of these is 'Smarter Pregnancy', an mhealth intervention conducted in the

Netherlands (Van Dijk et al., 2016). This intervention delivered personal online nutrition and lifestyle coaching, targeting both women only and couples contemplating pregnancy (n=1275) and already pregnant (n=603). After 6 months, significant improvements in health behaviours, including vegetable and fruit consumption, were shown, with strongest effectiveness amongst couples. The second study was a maternal nutrition intervention in Bangladesh which engaged husbands (Nguyen et al., 2018). The program involved husbands attending two forums on maternal nutrition and engaging in community events. A cluster-randomized program evaluation (n=622) showed that husband support, because of knowledge, awareness, self-efficacy and social norms, explained nearly half of the program impact (48%) on maternal supplement intake and nearly a quarter (22%) for diet diversity. Whilst neither of these took place in the UK and the context of the Bangladeshi study has little relevance to the UK, these studies illustrate the potential effect on intervention success of including partners. That only two such studies could be found points to the under-utilisation of partners in antenatal health intervention. More studies in non-pregnant populations, including pre-conception couples, have shown the positive effects, in terms of both physical and mental well-being, of including partners in the interventions (Arden-Close & McGrath, 2017; Homan, Litt, & Norman, 2012; Trief et al., 2019).

5.1.2 Baby Buddy expansion to include partner support

Best Beginnings identified the need for a fathers'/partners' version of Baby Buddy as early as 2014, although it was not until the development of Baby Buddy 2.0 that funding was secured to create a defined fathers'/co-parents' pathway. Not only do fathers/co-parents play a key role in their child's development, but also they have needs of their own as they transition to and develop in their new role as a parent (Levy & Kotelchuck, 2022; Yogman & Eppel, 2022). Best Beginnings' research (unpublished) showed there was an appetite for app-based information and support for fathers. A qualitative study I conducted in 2014 comprised one focus groups with dads and expectant dads (n=6) and one with midwives (n=8), as well as individual interviews with expectant dads (n=3), social care professionals (n=3) and health visitors (n=3). Participants from all groups felt that there were few resources designed specifically for expectant dads and that an app-based resource would be more accessible and appealing that print based materials. Other studies have endorsed the

view that resources for expectant fathers are lacking (Peyton & Wisniewski, 2019; Thomas, Lupton, & Pedersen, 2017).

Given the evidence for partner support positively impacting women's well-being and behaviours in pregnancy, and Baby Buddy's new fathers'/co-parents' pathway, a decision was made in conjunction with Best Beginnings to explore the potential of including partners in a healthy eating and physical activity intervention for pregnancy.

5.2 Aims

The aims of this study were two-fold:

- To provide qualitative insight into the role and influence of the partner on a pregnant woman's dietary and physical activity behaviours.
- To identify the barriers and facilitators to participating as a couple in a digital intervention targeting healthy eating and physical activity during pregnancy.

5.3 Methods

5.3.1 Theoretical framework

This study used thematic analysis to address the first aim of exploring the role and influence of the partner on a pregnant woman's dietary and physical activity behaviours. The COM-B model and the TDF provided the framework for investigating barriers and facilitators to participating as a couple in a healthy eating and physical activity intervention during pregnancy (see 3.2.2 for a detailed description of COM-B and TDF).

5.3.2 Study design

The study design was qualitative, using a combination of focus groups and individual interviews. Originally face-to-face focus groups and interviews were planned to commence in March 2020. However, COVID-19 restrictions delayed the start to July 2020 and focus groups were conducted online using the video conference platform Zoom, and individual interviews were carried out by telephone.

I chose focus groups as the most appropriate qualitative methodology for men as I felt they would create a more relaxed and interactive environment in which to explore views and experiences of a topic that men were likely to be unfamiliar discussing. Whilst such interaction also brings about more space for peer influence, my experience as a moderator helped to create an environment in which participants felt able to express their own views and mitigated posturing and peer influence, ensuring that the benefits of a group approach outweighed potential negative effects. In contrast one-to-one interviews were chosen for women, as here the aim was to explore personal experiences of partner support both in general and with respect to dietary and physical activity behaviours. I moderated all the focus groups and conducted all the interviews.

I designed topic guides for the focus groups and telephone interviews using open-ended questions to explore the experiences and role of partners in pregnancy, changes to health behaviours made by both men and women, sources of information about dietary and physical activity behaviours in pregnancy, including usage of pregnancy apps and response to the concept of an app-based intervention for couples to encourage the development of healthy eating and physical activity habits (see Appendix 4). The intervention concept was introduced to participants as *'A new app feature to help expectant parents develop healthy eating and exercise habits, with information and tips and the ability to set yourselves goals and track your progress'.*

Questions around the barriers and facilitators to the couples' intervention were guided by COM-B and TDF (Michie et al., 2011). The discussion flow was largely participant led, although I ensured the conversation stayed on topic and that all key topics were covered.

5.3.3 Participants

To ensure that study participants had experienced a whole or close to whole term of pregnancy and that it was still fresh in their minds, the sample comprised expectant parents in the last trimester of pregnancy and parents of babies $\leq$18 months old. Since maternal obesity and poor diet quality is more prevalent in those experiencing higher levels of deprivation, the majority of participants were recruited from groups with low

income and/or without tertiary education and/or from minority ethnic groups (PHE, 2019). Given the constraints of sample size and the importance of creating a relaxed and convivial environment for partners to share their views, I restricted the partners' focus groups to male partners only. No constraints were placed on the gender of partners in the women's sample.

5.3.4 Recruitment procedure

Due to restrictions as a result of COVID-19 an entirely remote recruitment methodology was implemented. Given the challenges of recruiting men from low income and minority ethnic groups into research, an a priori decision was made to use a professional market research agency, Apogee Group Recruitment, to recruit the men's focus groups. Participants were offered a £25 incentive. Participants for the women's telephone interviews were drawn from a convenience sample of respondents to a national online survey conducted by three organisations - Best Beginnings, Home-Start UK and Parent Infant Foundation. This online survey, conducted in April to June 2020, explored the views and experiences of expectant parents and parents of very young babies during the COVID-19 pandemic ("Babies in Lockdown," 2020). At the end of the survey respondents indicated whether they would be willing to take part in a follow-up telephone interview for Best Beginnings. Those agreeing were emailed by Best Beginnings and asked for their consent to pass on contact details to the team at UCL. This generated a list of approximately 250 names from which the sample was drawn. Priority was given to those meeting one or more of the indicators of deprivation outlined above. Due to limited ethnic diversity within this convenience sample, an extra mini focus group of Asian women was added and recruited by the professional market research agency.

5.3.5 Data collection

The focus groups and telephone interviews took place between July and September 2020. All the sessions were audio recorded.

5.3.6 Data analysis

Data were analysed using an inductive thematic approach (Braun & Clarke, 2006). All focus group and telephone interview audio recordings were transcribed and uploaded to NVivo 12 Pro (QSR International Pty Ltd. (2018) Nvivo (Version 12)). After re-reading all the transcripts and trial coding two focus groups and three telephone interviews, an initial coding framework was developed based on the responses of both men and women. A second researcher, Andrea Smith (AS), analysed, two focus groups and six telephone interviews (i.e. 50% of the data) using this coding framework. Any discrepancies over codes or coding definitions were resolved through discussion and a final coding framework was agreed. All transcripts were subsequently re-coded using this. framework. Identified themes were established through an iterative process of discussion with AS, refinement and development. Finally, the transcripts were revisited to confirm the legitimacy of the final themes. A third researcher, Helen Croker (HC) was involved at various stages throughout the coding and theme development process, to verify its accuracy and appropriateness. AS and HC also reviewed the mapping of the barriers and facilitators according to TDF domains and the COM-B model.

5.3.7 Ethics

Approval for this stage of research was granted by University College London Research Ethics Committee (16749/001).

5.4 Results

Three focus groups were conducted amongst men (n=15), and 12 telephone interviews and one mini focus group (n=3) amongst women (n=15). The focus groups lasted between 45 and 91 minutes (averaging 72 minutes), and the telephone interviews between 22 and 43 minutes (averaging 32 minutes).

5.4.1 Characteristics of study participants

Participant characteristics are summarised in Table 5-1.

Table 5-1: Characteristics of study participants

	Men n=15	**Women n=15**	**Total (%) n=30**
Age (years)			
<20	0	1	1 (3)
20-29	2	5	7 (23)
30-39	10	9	19 (63)
40+	3	0	3 (10)
Ethnicity			
White	5	9	14 (47)
Black	5	3	8 (27)
Asian	4	3	7 (23)
Mixed	1	0	1 (3)
Education (highest qualifications)			
No formal qualifications	3	1	4 (13)
GCSE	7	5	12 (40)
A level	5	1	6 (20)
Graduate	0	5	5 (17)
Post-graduate	0	2	2 (7)
Not stated	0	1	1 (3)
Pregnancy/baby status			
First pregnancy/baby	15	10	25 (83)
Second+ pregnancy/baby	0	5	5 (17)
Last trimester	0	2	2 (7)
Baby< 6 months	7	6	13 (43)
Baby 6-12 months	3	7	10 (33)
Baby 13-18 months	5	0	5 (17)

The 15 men in the sample were aged 27-44 years (mean 35 years) and of varying ethnic backgrounds (5 were Black, 5 were White, 4 were Asian and one was mixed ethnicity). None of the men had post-school qualifications and 3 had no formal educational qualifications. All of the men were first time fathers/expectant fathers. Nine of the men lived in London or the South East and 6 lived in the Midlands or North England.

The 15 women in the sample were aged 18-39 years (mean 31 years), and from a range of ethnic backgrounds; 9 were White, 3 Asian and 3 Black. Seven women had no post school qualifications and one declined to answer. Five women were

multiparous. The women in the sample were geographically spread across the UK (excluding Northern Ireland).

The majority of the sample had babies under 12 months old (n=23) and were first time parents or pregnant for the first time (n=25).

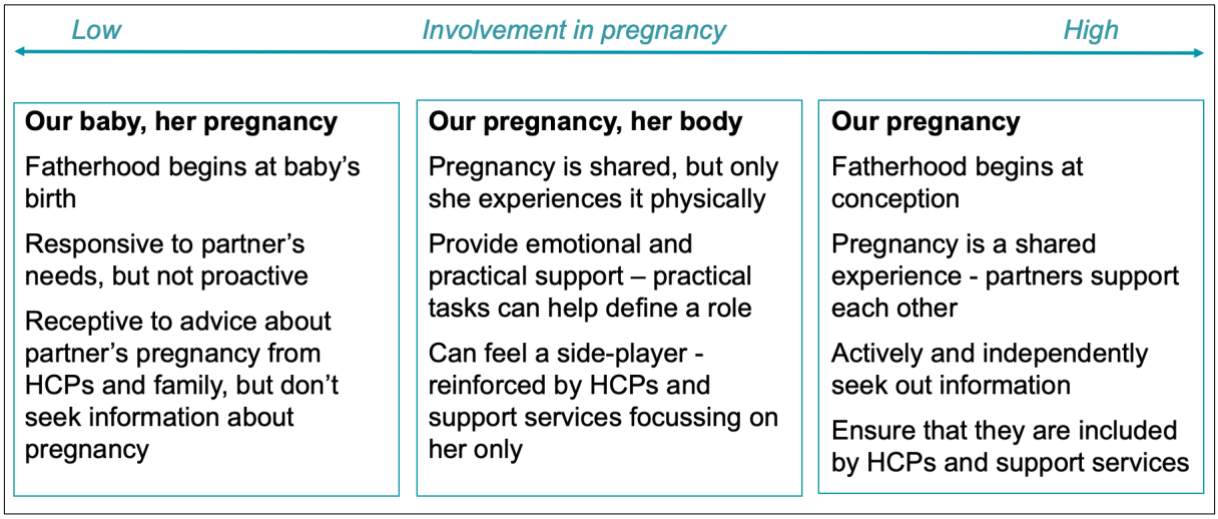
5.4.2 Themes

Four main themes relating to partners' role in dietary and physical activity behaviours in pregnancy were identified; (1) partner involvement and support; (2) partner understanding of good dietary and physical activity behaviours; (3) concordance of dietary and physical activity behaviours in couples; and (4) partner influence on her dietary and physical activity behaviours. These themes arose from comments made by all participants in the sample, that is men talking about their own attitudes, experience and behaviours and women talking about their views and experiences of their partners' attitudes and behaviour. No obvious differences emerged according to demographic variables or whether participants were first time parents and expectant parents and those who already had children, although the sample size of the latter group was very small (n=5). The themes provided a context for understanding barriers and facilitators to participating as a couple in a healthy eating and physical activity intervention during pregnancy.

5.4.2.1 Theme 1: Partner involvement and support

Experiences and attitudes of both men and women in the sample suggested a continuum of partner involvement and support in pregnancy, with three broad typologies of expectant fathers emerging as summarised in Figure 5-1

Figure 5-1: Level of partner involvement and support



Our baby, her pregnancy: The least involved expectant fathers were characterised by their view of the pregnancy being their partner's. They perceived pregnancy to be a 'woman's thing' and often talked about the active involvement of other female relatives in their partner's pregnancy. As they saw it, their role as fathers began only when their baby was born. For some participants these gender-stereotypical roles were rooted in family or cultural beliefs.

> *When we visited my in-laws, there was lots of questions …. mostly aimed at my wife….I did feel that I was on the outskirts, I wasn't shocked, as such…. I'd be sitting there watching football with the beers. (Male, #2)*

Whilst they were happy to support their partner in any way she wanted, they tended to adopt a reactive approach, taking the lead from her. Similarly whilst they were receptive to information, advice and guidance from their partner, other family members and healthcare practitioners (HCPs), they rarely sought it themselves.

> *I think it's widely known in the medical world and even outside of the medical world, that the expectation for self-educating yourself in pregnancy is the woman's role. (Male, #10)*

Women whose partners conformed to this typology tended to criticise the men for not understanding pregnancy and not being more proactive in supporting them.

They don't understand anything, the sleeping problems the sitting problems. Because my husband doesn't understand I do see it more of my pregnancy but our baby if that makes sense. *(Female, #15)*

Our pregnancy, her body: Sitting midway along a dimension of involvement, another group of participants expressed a view that whilst they felt pregnancy was a shared event, the physicality of the experience belonged to the woman. Expectant fathers in this group talked about their important role in providing practical and emotional support to their partner, but ultimately felt that the physical experience of pregnancy belonged only to their partner. For some this created a dissatisfying sense of being a side-player or worse, excluded.

I see it my role… is like a supportive role, like an auxiliary role, where you can't obviously take the main role, so you basically work like a mix between a waiter and being someone who's there for her. (Male, #6)

Sometimes men can feel a bit left out of the whole pregnancy because the woman goes through all the changes and has these massive mood swings…I felt like a bit of a spare part to be honest. (Male, #13)

For this group and for the previous group, men's experience of pregnancy support services and HCPs could reinforce their views on their role in pregnancy.

I felt that it (NCT) was that was very much geared towards the woman and in fact, I made the point that is there any point of me being here? (Male, #10)

Our pregnancy: The most involved expectant fathers in the sample were characterised by their belief that their role as fathers began at the beginning of pregnancy.

When we're talking about the baby he's always talking about our son, he's very much going to be part of the child's life, he wants to be part of it now. He talks to the bump. (Female, #5)

As such they were fully involved in all aspects of the pregnancy and made sure that HCPs understood and respected this. In addition to providing practical and emotional support to their partners, these expectant fathers took steps to inform and educate themselves about pregnancy. Some had downloaded pregnancy apps or joined social media groups for expectant dads.

> *It was definitely a team effort. Guys in the 21st century are a lot more on it. You look at the apps and you help where you can. (Male, #7)*

> *I made myself be involved – I wanted to know everything that was going on. So I wasn't going to wait - I was in first, asking them* (HCPs) *everything (Male, #14)*

Most women in the sample whose partners conformed to this typology supported their partners' view of seeing pregnancy as a shared adventure. They welcomed the level of support they received and were often aware of their partner's need for support too.

> *It was our pregnancy - it was our baby. We were pregnant – not just me. (Female, #7)*

> *He's very hands on. He's come to all my (antenatal) appointments ... As we've had more children he has looked after them so I can go and do something …it's divide and conquer…very involved in every aspect. (Female, #12)*

> *He felt left out – useless and he doesn't like feeling useless. It wasn't easy for him too (Female # 3)*

However, one participant voiced a concern about her partner's involvement bordering on controlling or 'policing' behaviour.

> *It's a little bit like he was policing me, but then again it goes back to this is our pregnancy, not mine - it was because he cared for me and baby. (Female, #7)*

5.4.2.2 Theme 2: Partner understanding of good dietary and physical activity behaviours

Levels of understanding regarding the importance of good dietary and physical activity behaviours in pregnancy varied in both men and women. Apart from the most involved expectant fathers, most men relied on their pregnant partner as their main source of information on this matter. Most men were aware of the relationship between maternal diet and baby's health and development and talked about 'healthy eating'. However few understood the risks to maternal and foetal health of poor dietary and physical activity behaviours. Awareness of conditions like GDM was largely limited to those who had experience of it. Likewise, partners' knowledge of what constitutes a healthy diet in pregnancy varied considerably. More health-conscious men and those who were more involved in the pregnancy talked about the value of specific food groups (typically fruit and vegetables) and nutrients. Others were vague, often referring to a 'normal' or balanced diet or simply highlighting dietary changes she had made.

> *I think we just kept it as normal cos we was (sic) already eating quite nutritious diet…as long as they're having these Pregnacare tablets, then that covers most of it. (Male, #6)*

> *She had a craving for double cheeseburgers from Mac Donald's, but she was making sure she was taking Pregnacare and Folic acid. (Male, #9)*

Understanding of the importance of keeping active and exercising for maternal and foetal health was limited. Typically, only those who already were quite committed to exercise knew of its benefits in pregnancy. Others were unsure what type or amount of exercise was safe in pregnancy, tending to believe it was safer to avoid exercise apart from walking.

> *It's taken us, it took us a long time to get to this point and we didn't want to throw it away for the sake of doing you know, one gym session a week, or running or, or even fast walking. (Male, #10)*

I see some pregnant women doing push ups and running and I stand there in amazement thinking is it really worth taking that risk? (Male, #7)

5.4.2.3 Theme 3: Concordance of dietary and physical activity behaviours in couples

Most participants reported a high degree of concordance of dietary behaviours with their partner, and since many women had made changes to their diet during pregnancy, many expectant fathers had, by default, done so too. Generally these had been healthier changes, such as increasing fruit and vegetable intake or decreasing snack foods and takeaways. However, participants also reported worsening dietary behaviours.

So whatever made her sick is basically what we what we stopped eating. (Male, #1)

I think my wife's diet sort of lapsed or relaxed….I think that why a lot of guys like me put on weight during pregnancy because my wife's lifestyle choices meant she didn't have the energy to cook and therefore it was easy for me to pick up the phone and ring for a pizza or whatever. (Male, #10)

He put on a bit of sympathy weight during pregnancies…. I was getting hungry and I think he just started to eat more as well….bigger portions at mealtimes. (Female, #10)

For the majority, concordance in dietary behaviours was driven by convenience of preparing (or ordering) one meal rather than a view that expectant fathers should also make dietary changes. Indeed men generally did not feel the need to sacrifice their own preferences.

She tried to eat a lot more healthy, like vegetables which she wouldn't normally do. I tried but I must admit I don't like salads and that. (Male, #11)

However, for a small minority of more involved expectant fathers, concordance was motivated by a desire to show support and solidarity.

> *I mean, it's definitely difficult when you will want to get the take-away or something but she can't really eat it. Sometimes you'd have to sacrifice your pleasure. (Male, #4)*

> *Well he actually started to take smoothies as well, and the disgusting vitamins because like, he didn't want me to feel singled out. (Female, #2)*

Unlike in dietary behaviours, participants rarely reported couple-concordance of physical activity behaviours, either in the type or amount of exercise taken or general activity levels. The only exceptions to this were firstly the tendency for men to share more household duties and secondly couples taking walks together, particularly towards the end of the pregnancy.

> *….allowing her to not do the things she might have done before, that are a bit strenuous. So kind of taking work away from them. (Male, #6)*

> *Hold her hand and walk with her to the park … because the doctors and the nurses say she has to walk a bit – 100 to 200 meters a day - because she was suffering from diabetes. (Male, #12)*

5.4.2.4 Theme 4: Partner influence on her dietary and physical activity behaviours

Only a small number of more health-conscious men in the sample actively encouraged their pregnant partners to adopt better dietary and physical activity behaviours.

> *When I was pregnant, he was then cooking more because I was either having a nap or I was tired or whatever. So he would be consciously trying to put veg and stuff like that into my diet. (Female, #3)*

Diet-wise, most men felt their role was to concur with her choices. This was particularly apparent in men's tendency to enable their partner's cravings.

> *That's the best way to placate them – if they say KFC you just go get KFC. If they say Burger King, you just go get it – no opposition no question just get it. (Male, #14)*

Indeed, some men reported that even when they felt their partner was eating the 'wrong' food or gaining too much weight, they would keep quiet to keep peace.

> *I'll tell you what anyone who says they are not going to say let it slide for the day…I'd rather fight the battles I can win. If they are already feeling body conscious, they already know a packet of custard creams isn't going to do them any good, there's not point me telling them that and making them feel worse. (Male, #13)*

There was some evidence of men unintentionally encouraging unhealthy dietary behaviours, which appeared to be rooted in cultural beliefs.

> *Everyone kept telling me to eat for two – maybe it's in our culture - Bangladeshi culture. (Female, #15)*

> *My mother-in-law, even my husband, all my family were saying you've got to eat for two. (Female, #13)*

Similarly, some men were encouraging their partners to avoid exercise or any overly strenuous activity, partly because they felt allowing her to relax and rest was evidence of their support and partly because their belief that it was unsafe in pregnancy.

> *I don't know what other exercises are acceptable in pregnancy, I have no idea, so we stuck with walking. (Male, #1)*

> *He'd do all the housework, which was very unlike him. He wouldn't let me lift or carry anything (Female, #3)*

5.4.3 Barriers and facilitators to participating as a couple in an intervention mapped to COM-B and TDF.

Table 5-2 summarises the identified barriers and facilitators to participating as a couple in a digital intervention to encourage healthy eating and physical activity in pregnancy. Barriers and facilitators were largely different for men and women, although some were common to both. The most highly populated COM-B domain was Reflective Motivation (see 3.2.2), with TDF Identity, Goals and Intentions being particularly pertinent to men and Belief about the Consequences to women.

5.4.3.1 Reflective Motivation

<u>Identity, goals and intention</u>

A key motivation for men to participate in the intervention was their desire both to be a supportive partner and to have a defined role within the pregnancy. Whilst some regarded participating in the intervention to be evidence of their existing commitment to their partner and their pregnancy, others saw it as a way of increasing their involvement and support. Women too viewed their partner's intention to be supportive as a facilitator to his participation in the intervention.

> *To have something that is partner oriented for the two of you, that would really help. A lot of guys want to be involved now, it would appeal to so many people. (Male, #9)*

> *He would definitely cut down on KFCs if he thought it was better for me and the baby … anything to make it work and support me with this. (Female, #4)*

Table 5-2:COM-B and TDF mapping of barriers and facilitators to participating as a couple in a digital healthy eating and physical activity intervention as identified from the qualitative interviews (n=30)

COM-B factor	TDF Domain	Barriers	Facilitators
Motivation Reflective	Identity/goals	'Her pregnancy' -fatherhood begins at baby's birth (Partner)	'Our pregnancy' (Both) Being a fit and healthy father (Partner) Being a supportive partner (Partner) Being a good role model to child (Both)
Motivation Reflective	Beliefs about consequences	Potential conflict/controlling behaviours (Woman)	Increase commitment and hence improve success rates (Woman) Give partner (more of) a role in pregnancy (Both) Positively impact relationship (bonding) (Both) Improve partner knowledge and hence support (Woman)
Motivation Reflective	Intentions	_	Commitment to be a supportive partner during pregnancy (Partner)
Motivation Automatic	Emotions	_	Feeling supported (Woman) Feeling included (Partner)
Opportunity Social	Social influences	_	HCP recommended (Both)
Opportunity Social	Social norms	'Her pregnancy' and cultural/family gender stereotyping (Both)	'Our pregnancy' – partners today are involved (Both)
Opportunity Physical	Context and resources	Cost and time of participating together (Both)	Existing concordance in energy balance behaviours (Both)

COM-B factor	TDF Domain	Barriers	Facilitators
Capability Psychological	Knowledge	_	Understand the importance of good energy balance behaviours to mother's and baby's health (Partner) Understand the importance of partner support in her achieving healthy energy balance behaviours (Partner)
Capability Physical	_	_	_

Note.

Woman = Expressed by pregnant woman only

Partner = Expressed by pregnant woman's partner only

Both = Expressed by pregnant woman and her partner

The opposite of this was the belief, alluded to rather than explicitly identified as a barrier to participation, that a man's role as a father does not begin until the baby is born.

> *At my early stages I didn't get much attention but now he can see the bump I get more attention. (Female, #14)*

> *At risk of sounding uncaring, I didn't really have to change much to be honest….I think she more or less had it under control. I didn't really have to do anything. (Male, #1)*

A desire to be a fit and healthy parent and a good role model for their child was a facilitator, for men especially. Even those who subscribed to the 'her pregnancy' point of view could be motivated by the potential benefits to themselves of jointly engaging in a healthy eating and physical activity intervention.

> *I don't want to be a fat unhealthy dad…I want to be healthy into my old age. (Male, #3)*

> *I'm not gonna lie – come that sports day when they go to primary school, I don't want to be the last dad! (Male, #10)*

> *You don't want to be a lazy dad sitting on the sofa (Male, #11)*

<u>Beliefs and consequences</u>

Particularly motivating to women was the belief that working together as a team would increase the likelihood of adhering to the chosen health behaviour.

> *I think it's a good idea because mutual support is the best way to make changes. It's almost impossible to make a change to your diet if one of you is doing it and one of you isn't. (Female, #5)*

Some women recognised in themselves a need to be accountable to someone else in order to stick to commitments.

As soon as I have told somebody it's like I've committed to it, but if I've only kept that to myself. Then I can say to myself well I didn't really want to do it or I'll find an excuse not to. (Female, #6)

Women also mentioned the benefit to their partners of participating jointly in that this would create a tangible, actionable role for partners and help them to feel involved.

Because partners I think, like, males are the other partner that isn't pregnant, like some of them don't feel like very included but if they had the app as well, they would probably feel more involved as well. (Female, #2)

More broadly, both men and women also identified the potentially beneficial consequences on the partner relationship of working towards goals together. The opportunity to bond through a shared goal was particularly appealing both to those who found pregnancy a bonding experience and those who had struggled more with the changes it had brought to their relationship.

I think it's a good idea – you can both get involved and it would bring you both together (Male, #9)

And I think people would respond well to having something to do together because there is that feeling that they are bonded together at a time when other things are changing and it can be quite scary. (Female, #6)

Women whose partners were at the least involved end of the spectrum were motivated by the thought that a couple's intervention could improve their partner's understanding about pregnancy and thereby lead to him supporting her better.

I think the app will help for the husbands because they will understand more and this way we'd get more support from them, because they'd understand more. (Female, #13)

If someone was to tell him maybe don't have too much sugar during your pregnancy he might be like you're not actually meant to have this, give it to me. Because they don't know all they hear from their

mothers is eat for two, eat for two and they probably think they are doing the right thing by feeding me. (Female, #15)

Some men also pointed out the opportunity the intervention might offer for self-education around pregnancy and improvement of their skill set.

All the advice that we can get is better because, you know, we can't be expected to know everything. (Male, #6)

The only barrier identified in the context of beliefs about consequences was an anticipation that participation might lead to conflict between couples, particularly if the intervention focussed on weight gain issues.

You would have to have good faith on your partner that they're able to motivate you without it being of a matter of them nagging you - you're putting on weight, dear and you need to be healthier….It would start off nicely and he'd be encouraging and eventually he would grate on me and I'd be saying I'm not doing it. (Female, #11)

One woman was concerned that the intervention might give her partner permission to be overly controlling over her dietary and exercise behaviours.

5.4.3.2 Automatic Motivation

Emotions

Pregnant women identified the warm feelings of togetherness and being supported as a facilitator whilst men talked about being and feeling included.

I need your support and I want you to do it as well, so I don't feel like I'm on my own. (Female, #8)

I'd say you'd feel a lot more involved…. my own experience, I felt like I didn't really have any role. (Male, #1)

You need to feel that you and your partner are close together and you are not alone in anything. (Female, #6)

5.4.3.3 Physical Opportunity

Context and resources

Couples' concordance of dietary behaviours and in taking walks was perceived to be a facilitator in a practical sense of fitting in with existing behaviour and lifestyle patterns.

> *We cook together we eat together so we're eating the same, the same meals. (Female, #5)*

However, the time and effort involved in coordinating activities and the cost of both eating healthier and potentially more expensive foods were occasionally cited as barriers.

> *I think that the barriers will be maybe time and trying to get organised, (Female, #1)*

> *(He) would have his own rice… white rice and I'd have a wholemeal rice…. When you're looking after the pennies cos you've got a baby on the way it (wholemeal) can be quite an expensive option. (Female, #8)*

5.4.3.4 Social Opportunity

Social norms

Perceiving pregnancy as 'ours', i.e., a shared experience, emerged as a facilitator to participating as a couple. Conversely, perceiving pregnancy as 'hers', a view that appeared to be propagated by family and cultural gender stereotyping, might be a potential barrier, although this was alluded to rather than openly voiced in this research.

Social influences

HCP endorsement was identified as an important facilitator to participating as a couple. Men claimed that they would be even more likely to participate in the

intervention if it was suggested to them by the midwife or GP. Not only would this validate the credibility of the intervention, but also it would confirm and 'allow' the importance of the partner's role in pregnancy. Similarly, women could feel that HCP recommendation would legitimise their desire for greater involvement and support from their partner.

> *It would be like a stamp of approval from the NHS. When it's being recommended by a health professional it carries a lot of weight. (Male, #8)*

> *If it was for the father, coming from the midwife makes us be part of the process I would value that because I am being included. (Male, #3)*

5.4.3.5 Psychological capability

Knowledge

Having good understanding of the importance of good dietary and physical activity behaviours to maternal and foetal health appeared to be a facilitator for men in that it enabled them to appreciate value of working with their pregnant partner to reduce the risk of adverse health outcomes. Understanding of the potential impact of partner support during pregnancy worked similarly as a facilitator.

> *It should talk about how it helps your baby and how it helps your relationship rather than just it's good for you. You hear that message – it's good for you – all the time. (Male, #13)*

5.4.3.6 Physical capability

Participants did not identify any barriers or facilitators to participating in the intervention as a couple that fell within the physical capability domain.

5.5 Discussion

This qualitative study used focus groups and individual interviews amongst expectant and recent parents (n=15 men, n=15 women) to explore partners' role in dietary and

physical activity behaviours during pregnancy. Using COM-B and TDF, the study identified barriers and facilitators to participating as a couple in a digital intervention targeting healthy eating and physical activity. Four themes around partners' role in dietary and physical activity behaviours were identified; partner involvement and support; partner knowledge of the importance of good dietary and physical activity behaviours; concordance of dietary and physical activity behaviours in couples; partner influence on her dietary and physical activity behaviours. Differing levels of partner involvement and support during pregnancy were broadly related to partners' level of understanding of the importance of dietary and physical activity behaviours to maternal health. Concordance of dietary behaviours was widely reported, although couples' exercise behaviours tended to be less alike. Partners rarely seemed to be a positive influence on women's dietary choices, typically deferring to her desires, particularly regarding cravings. Caution over the safety of exercise in pregnancy meant men could be a negative influence on women's exercise behaviours. Most facilitators to participate as a couple in an intervention lay within the Reflective Motivation domain of COM-B. Men's motivations derived from their desire to be involved – or even have a defined role - in the pregnancy as a supportive partner, to be a fit and healthy father and to be a good role model for their child (TDF: Identity, Goals and Intentions). Women were motivated by the belief that a couples' intervention might increase their partner's understanding and support, and a joint effort might improve their likelihood of success in achieving dietary and physical activity goals (TDF: Belief in Consequences). The opportunity for greater couple bonding was also highlighted as a potential motivator, although couple conflict was a barrier for women who anticipated their partner being controlling. Within the Social Opportunity domain, HCP recommendation to join a couple intervention was seen as a key facilitator, both legitimising the role of partners in the pregnancy and adding integrity to the intervention. Conversely, certain cultural beliefs around the role of men in pregnancy were reported as potential barriers to engagement (TDF: Social Influences). Within the Psychological Capability domain understanding the importance of good dietary and physical activity behaviours to maternal health and the value of partner support was a facilitator to intervention participation (TDF: Knowledge).

This research echoes the findings of previous studies reporting men's desire to be involved in pregnancy and to support their partner (Steen, Downe, Bamford, &

Edozien, 2012; Xue et al., 2018). In this study men who were at the low to mid end of the spectrum of involvement believed that participating in an intervention with their partner would give them a greater role within the pregnancy and help them feel included and more valued. A meta-synthesis of expectant fathers' experiences of pregnancy concluded that if HCPs made greater efforts to involve fathers, this would increase their sense of being valued and place them in a better position to support their pregnant partners (Kowlessar et al., 2015). The present study also identified HCPs' recommendation as a key facilitator to participating in a couples' intervention in that it both acknowledged the importance of partners in pregnancy and endorsed the trustworthiness of the intervention. Men also identified other, more self-oriented, motivations to participating in the intervention – a desire to be a fit and healthy father and to be a good role model for their child. Given that weight gain in men during pregnancy is quite common, the potentially positive effects of a couples' intervention on men's dietary and physical activity behaviours is also important (Garfield et al., 2016). Identifying that these messages can be motivating to expectant fathers sets out a practical, feasible and useful type of content to include in the intervention messaging that might increase partner engagement.

A key finding of this study was that women believed they would be more likely to succeed in improving their dietary and physical activity behaviours during pregnancy if their partner was working with them towards shared or similar goals. It is surprising that few studies have examined the effect of partner support on dietary and/or physical activity behaviours in pregnancy, although two previous interventions that included partners both showed promising results. In Bangladesh engaging husbands in a maternal nutrition program substantially contributed to their partners' better dietary practices during pregnancy (Nguyen et al., 2018). The authors showed that husband's support, because of their knowledge, awareness, self-efficacy and social norms, explained nearly half of the program impact on maternal supplement intake (48%) and nearly a quarter for diet diversity (22%). However this was undertaken in a very different cultural context, so direct comparison to the UK and the use of a digital delivery mode are challenging. Smarter Pregnancy, an mhealth intervention in the Netherlands (n=1172) targeting vegetable and fruit in pregnancy reported a 26.3% increase (95% CI:23.0, 29.9) in the number of participants achieving adequate vegetable intake and a 38.4% increase (95% CI:34.5, 42.5) for fruit intake, with a

greater effect amongst couples (n=353) than women undertaking the intervention alone (Van Dijk et al., 2016). Studies in preconception couples and non-pregnant populations have also shown the positive effect of couple-inclusion on dietary and physical activity behaviours (Arden-Close & McGrath, 2017; Homan et al., 2012) and an RCT of a mobile preconception lifestyle programme for couples is currently underway (delayed because of COVID-19) in Belgium (Boedt et al., 2019).

Beyond the physical health benefits of participating in an intervention as a couple, this research indicated there may be benefits to couples' emotional and relationship well-being. The association between partner support and maternal mental wellbeing has been demonstrated. Tanner Stapleton et al. measured partner support in 272 women mid-pregnancy and found women who perceived stronger social support from their partners had lower emotional distress at 6-8 weeks postpartum after controlling for their distress in early pregnancy (Tanner Stapleton et al., 2012). In their qualitative study exploring women's use of pregnancy apps (n=21), Hamper and Nash (2021) discuss the way in which apps are used to create a bond with the unborn baby (Hamper & Nash, 2021). By sharing app information, women encourage their partners to connect with the baby and share the responsibilities and pressures of pregnancy. Taken together, these insights highlight that the potential benefits of greater partner involvement in the pregnancy and couple bonding should not be underestimated.

This research concurred with findings from previous studies that women's dietary behaviours in pregnancy are influenced by their partners, friends and family (Flannery et al., 2020; Grenier et al., 2020). Hill argues for a shift from a focus on the pregnant women being solely responsible for her lifestyle choices and suggests a new socioecological framework for maternal obesity which recognises the many layers of influences on women's behaviour (Hill, 2021). An intervention aimed at couples could begin to shift the focus from women only and recognise these broader influences. Hill argues that a shift in focus would help to reduce weight stigma and blame, issues that participants in the present sample identified as a source of couple conflict and as such a potential barrier to the intervention. Repositioning the emphasis from GWG and maternal responsibility onto improving dietary and physical activity behaviours for couples or parents as they embark on this new life stage is more likely to benefit long term family health and contribute to ongoing efforts to reduce childhood obesity.

Whilst the potential for engaging partners appears promising, risk of partner involvement in the intervention leading to controlling behaviours should not be overlooked. Despite the issue of potentially negative consequences of partner involvement being discussed in all the interviews, only one participant felt it might be problematic, although as a socially undesirable trait there is a risk that others preferred not to disclose their concerns. As such providing the opportunity to engage in the intervention without a partner, either alone or with a family member or friend as support will be important and ensure inclusivity.

In conclusion, this research has important implications for the type of messages that may promote couple-uptake of a digital intervention to encourage healthy eating and physical activity. By mapping barriers and facilitators to participating as a couple, the importance of the reflective motivation domain as a source of both potential motivators and barriers to engagement has been identified.

5.5.1 Strengths and limitations

A strength of this study is that it makes a significant contribution to the sparse body of literature investigating partners' role in dietary and physical activity behaviours during pregnancy. A further strength of this study is the use of theory, i.e. the COM-B and TDF, to systematically examine the barriers and facilitators to participating in a dietary and physical activity intervention as a couple. Moreover, the study sample purposefully represented population groups who are most at risk of poor dietary and physical activity behaviours, excessive GWG and maternal obesity. It should be noted however that participants were pre-informed as to the discussion topics and as such there was some risk of self-selection bias in the sample. Whilst participants expressed a range of opinions and behaviours with respect to diet and exercise in pregnancy, it might be that on balance they were more inclined to positive dietary and physical activity behaviours than the general population, of higher health literacy and/or more motivated and able to engage in healthy lifestyle behaviours. Consequently their responses to the intervention ideas presented to them might have been more positive than those of a completely random sample of expectant parents. Moreover the potential effect of social desirability bias cannot be ruled out when discussing these lifestyle issues. A further limitation of this sample was that all participants appeared to

be cohabiting and in stable, loving relationships where the pregnancy had been welcomed. Consequently, even male participants who represented the lower end of our spectrum of involvement in pregnancy appeared to be committed to their partners and the pregnancy and therefore potentially more receptive to a couples' intervention.

A limitation of any qualitative study is researcher subjectivity in the interpretation of the findings. To mitigate the effects of this, each stage of thematic analysis was reviewed by a second and in some instances a third researcher. This team of three debated and challenged each other's viewpoints as part of the analysis process. Finally, whilst the ethnic diversity of the sample provided insight into cultural differences, the small sample size meant some minority groups were not represented.

5.6 Conclusions

This research suggests an opportunity exists to harness partner support to improve maternal dietary and physical activity behaviours. Facilitators to participating as a couple in a digital healthy eating and physical activity intervention indicate that its benefit could extend beyond physical health, to couples' emotional and relationship well-being. Men appreciated the opportunity such an intervention would give them to feel more involved in the pregnancy, support their partner and prepare to be a fit and healthy father. Women also valued its potential to enhance partner involvement and support. In addition, they were motivated by the prospect of a team effort improving their chance of success in achieving dietary and/or physical activity goals.

A couples-based intervention should be a good fit with Baby Buddy 2.0 given its pathway for partners (currently fathers although a same-sex partners pathway will be created when funding allows for this). However, a version of the app for single parents will need to be designed for those registering with Baby Buddy as such, and those wishing not to include their partner in the intervention. This option will encourage users to find a family member or friend to support them through the programme, so as not to lose the important element of social support.

Chapter 6 Study 2b: A qualitative study exploring reactions to a rudimentary intervention design concept and generating ideas for its development.[4]

This chapter reports on the second part of the findings of Study 2, the qualitative study as described in the previous chapter, comprising online focus groups and telephone interviews with expectant parents and parents of a baby of up to 18 months old. Responses to a rudimentary intervention concept design were explored and participants were encouraged to generate and develop ideas for the intervention. This feedback helped me to design the detail of the intervention in a way that met potential users' expectations, needs and desires.

6.1 Introduction

In addition to investigating initial qualitative responses to the concept of a digital antenatal diet and physical activity intervention for couples, participants' reaction to a rudimentary concept were explored and their ideas for its design, content and tone ascertained. Following the initial set of questions presented in the previous chapter (Study 2a), the rudimentary hypothetical intervention concept was presented as '*A new app feature to help expectant parents develop healthy eating and exercise habits, with information and tips and the ability to set yourselves goals and track your progress'.*

The rudimentary concept was based on the findings of Study 1 that identified goal setting and self-monitoring as key BCTs (see 4.4.5). It was kept purposely vague in order to allow and encourage participants to contribute their own thoughts and ideas as to what form it should take. Weight monitoring was omitted from this initial description as Best Beginnings was unclear as to whether a weight monitoring feature

[4] A version of this study, along with Studies 3 and 4, has been published in JMIR Formative Research. Rhodes A, Pimprikar A, Baum A, Smith AD, Llewellyn CH. Using the Person-Based Approach to Develop a Digital Intervention Targeting Diet and Physical Activity in Pregnancy: Development Study. JMIR Form Res. 2023 May 26;7:e44082. doi: 10.2196/44082. PMID: 37234026; PMCID: PMC10257111.

would be acceptable within Baby Buddy given NICE currently does not recommend routine weighing or weight gain guidelines for pregnant women (*Recommendation 2*, National Institute for Healthcare and Excellence, 2010). Nevertheless, GWG was discussed with participants (and typically raised by them in the first instance) in order to elicit their views on whether and how to include the topic in a digital antenatal intervention and their reactions to GWG guidelines.

6.2 Aims

The aims of this study were to explore reactions to the rudimentary intervention concept and to generate ideas for its development.

6.3 Method

The reader is referred to section 5.3 for a full description of the study design, participants recruitment procedure and data collection. Inductive thematic analysis was used to examine and organise the findings (Braun & Clarke, 2006). The themes were then mapped to COM-B and TDF (see 3.2.2 for a description of COM-B and TDF).

6.4 Results

6.4.1 Characteristics of study participants

Participant characteristics are summarised in **Error! Reference source not found.**

6.4.2 Themes

Participants responded positively to the rudimentary intervention concept of *'a new app feature to help expectant parents develop healthy eating and exercise habits, with information and tips and the ability to set yourselves goals and track your progress'*. A total of 11 themes were identified with respect to expectations and desires for the intervention, three of which related to the intervention content and eight to intervention tone, scope and delivery style (see Table 6-1). Responses were broadly consistent across the sample, with minor differences reported below.

Table 6-1: Summary of themes

Intervention Content Themes (n=3)	**Intervention Style Themes (n=8)**
Providing a 'Why?'	Support me
Explaining the 'What?'	Make it easy to use
Providing guidance on the 'How?'	Make it fun to use
	Keep us interested
	Give us flexibility
	Make it shareable
	Reward us
	Make it personal

6.4.2.1 Theme 1 (Content): Providing a 'Why?'

Participants were unanimous in their opinion that rather than simply instructing expectant parents to eat a healthy diet, keep physically active and achieve a healthy weight gain, this intervention should emphasise and explain why these behaviours and goals are so important during pregnancy and to future family life. Many felt that the ubiquity of healthy lifestyle messages in society today had diluted their potency to the extent that they had become easy to ignore. Accordingly, being explicit about the benefits to maternal and foetal health was considered essential, both to strengthen the rationale for engaging in the intervention and to fill gaps in users' knowledge.

> *If it says this is harmful to your baby or this will be more beneficial instead. I think that would probably work better than... I mean all the medical professionals, the dietitian and everyone's all banging on about how good fruit and veg. and everything is. (Male #1)*

> *I know young mums and all that are actually really curious about the diets and all that…When I was pregnant, I had a lot of questions, but I forgot what they were, but I remember some of them weren't answered, but a place where you could get them answered would be really good. (Female #2)*

Whilst learning about the risks associated with poor diet and inactivity during pregnancy was considered important, discussion of the risks of excessive GWG provoked a divisive response. Some women, particularly those who had experienced postpartum weight retention, were keen that the intervention communicated the risks of excessive GWG. However, others were adamant that as a highly emotive issue, the topic of GWG should be avoided. Participants with overweight or obesity were particularly vociferous about their dislike of focussing on weight gain, reporting that it would induce feelings of guilt or discomfort at a time when weight gain was inevitable and as such was likely to prompt their disengagement with the feature. Moreover, most women believed that the level of weight gain in pregnancy was idiosyncratic; they were guarded and doubtful of the idea of a correct amount.

> *Speaking as someone who's had weight problems most of my life, I'm trying to have a mindset of I want to be healthy … getting 'well done' (on your weight) is probably not so good. (Female #5)*

6.4.2.2 Theme 2 (Content): Explaining the 'What?'

Participants were keen for the intervention to provide comprehensive advice on what exactly constitutes healthy eating in pregnancy, beyond generic messages such as '5 portions of fruit and vegetables a day'. Many felt this advice had been missing in their antenatal care. Few participants were interested in understanding dietary requirements at a nutrient level, with most simply wanting advice on what foods to eat to ensure their baby got the necessary nutrients. In addition, participants were keen that the intervention addressed misinformation and myths about diet in pregnancy, in particular the idea that women should be 'eating for two'.

Guidance on physical activity was seen to be equally as important. Participants, men especially, were often unsure as to what amount or type of physical activity was safe during pregnancy, leading to an assumption that avoidance of all but walking was the safest option.

> *I think just some information on kind of what you can actually do, coz I think I was just probably playing it safe with walking. That's*

pretty boring. There might be other things that you can do that you just don't really know about. (Female #3)

6.4.2.3 Theme 3 (Content): Providing Guidance on the 'How?'

Participants were keen for the intervention to show them how to develop healthier dietary and physical activity habits, giving them both practical advice and tools for the behaviour change process, and strategies for avoiding the common pitfalls. There was considerably less interest in the provision of information about or functionality for weight monitoring for reasons discussed in theme 1. Whilst this research did not explicitly explore barriers to healthy eating and physical activity in pregnancy, participants were keen that the intervention included topics such as pressure from friends and family; eating healthily on a budget; finding the time, energy and space for physical activity after a hard day at work or coping with the pressures of childcare.

Ways that you could easily fit it in during the day. You could do this particular thing while you're waiting for the kettle to boil. (Female #8)

Participants identified a goal setting feature and the ability to self-monitor or track behaviours as being important tools to help them develop healthier habits. Reminder notifications to complete or record a behaviour were regarded as essential and some participants suggested a diary to record more qualitative elements of their journey.

In terms of feedback on their progress, participants desired weekly personalised notifications summarising their achievements and providing appropriate congratulations, encouragement or tips on how to improve performance. Additionally, notifications when goals were achieved were suggested by some.

Feedback always helps – it's really good because then it's not a one-way thing. If you are getting something back it definitely drives you on. And there's that competitive element as well – that reward. You want to do better and achieve more... Competitive against yourself (Female #6)

Participants wanted the intervention to include an extensive range of healthy eating and physical activity ideas. They were particularly keen for recipe ideas that were

quick, easy, cheap and achievable for those with limited cooking experience. Ideally, they expressed the desire for such a repertoire to cover world cuisines and include vegetarian and vegan options. Several participants suggested a feature enabling users to share recipe ideas with other users. Similarly, physical activity ideas were expected to offer a wide variety of recommendations, including short, simple exercises that can be done at home and longer workout routines.

> *Having a recipe resource is obviously very useful, especially if it's going to be food that is gonna be beneficial to the baby as well. (Male #6)*

> *So I think if there's like quick, convenient, kind of like meals on there and things and maybe like tips and things to get more protein and things like that into diet without being in the kitchen for hours and hours. (Female #3)*

Men wanted advice and guidance on how they can provide practical and emotional support to their partners in achieving healthy eating and physical activity goals.

> *What I would suggest putting into the app would be practical things that the man can get more involved with….for example, there was some meals that could be cooked easily by a man which would benefit the pregnancy development. (Male #10)*

6.4.2.4 Theme 4 (Style): Support Me

Participants were concerned that whilst the intervention should be informative, it should avoid an authoritative or instructive tone. They did not want to be told what to do, to be patronised or made to feel guilty in any way. Rather they felt that the intervention should offer support and encouragement whilst acknowledging the many challenges facing pregnant women.

> *But it's about delivery, you don't want it to be condescending – the midwife making you feel guilty. You need to make sure there is a certain level of equality in how you speak to parents then you won't get men protesting or anything. (Male #7)*

Sometimes around pregnancy things can come across as a bit naggy, but useful tips that you can either take on board or not is a good idea. (Female #10)

6.4.2.5 Theme 5 (Style): Make It Easy to Use

Of paramount importance was that the intervention and all its features were easy to use. Many participants talked about downloading apps which they subsequently failed to use because of the effort they required either to set up or to use once set up. If setting goals and recording behaviours was not intuitive or required too much effort, participants felt they would be unlikely to use such functionalities. Information was expected to be easily accessible and delivered in bite-size chunks typical of social media apps. The use of video and visual images was suggested to reduce reliance on text, with links to more detailed articles for those with an interest to read more on a particular topic.

Whenever I have used an app it depends on how easy it is. Some you have to try hard to find the information – if they are accessible and easy it would be more appealing. (Male #8)

I'd like something that was continuously reminding you, like small notifications – like an Instagram pop up – maybe it's just my age group but that would help me focus more rather than a message that says there's a new blog out read it. (Female #15)

6.4.2.6 Theme 6 (Style): Make It Fun to Use

Participants felt that it was very important that the intervention be fun to use. In this respect, they suggested the inclusion of unusual and interesting facts, and fun challenges.

And maybe like a lot of fun facts like, the Romans used to eat this kind of food or how it was made. I think funny things as well - make it not sound really, really serious. (Female #2)

Visual elements like graphics to illustrate an individual's progress towards a goal and virtual rewards were also thought to be important.

I had a Fitbit before I had the baby and I think that worked really well. You set the step count you want to achieve in a day and when you hit that it would flash and the whole screen would be taken over with rainbows and fireworks. (Female #6)

6.4.2.7 Theme 7 (Style): Keep Us Interested

Growing bored of an app, particularly fitness tracking apps and other apps where the content remained the same over time was something that many participants saw as a barrier to usage. Whilst regular notifications of new content were seen as the most obvious way of averting boredom, other suggestions included tying the programme to the developmental stages of the baby to create a sense of change and progression, introducing regular new challenges and encouraging new goal setting at various stages. Regular personal feedback, sharing posts with other participants (i.e. creating a type of social network) and rewards were also suggested as ways of maintaining interest.

6.4.2.8 Theme 8 (Style): Give Us Flexibility

Participants were keen that the intervention could be tailored to meet an individual's needs as much as possible. Flexibility was sought in terms of how they could engage in the intervention, for example, giving participants the option to amend the intervention to focus solely on diet, physical activity or both and to choose whether to participate with or without a partner. Flexibility around goal setting was also considered essential, to allow individuals to choose their preferred type and frequency of the behaviour. Participants wanted to be able to set the timing and frequency of reminders to complete the behaviour and record it. The ability to opt out of reminders was also thought to be important.

6.4.2.9 Theme 9 (Style): Make It Shareable

Participants expected an intervention targeting both parents to include dedicated spaces within the app for couples to share their progress and highlight information, tips and challenges of particular interest to themselves. Presenting the use of such spaces as optional was deemed important given that some users might want to use the feature on their own. Many participants, including single parents were keen to allow

for flexibility to extend the concept of shared spaces to other family members or friends, or even an antenatal group, to increase motivation, inspire each other and to share ideas and tips.

> *Could there be an area like a forum on the app where you could discuss healthy eating options? Having peer support was really important for me. (Female #4)*

Views on whether progress data should be shareable were mixed. Whilst some men thought the idea of competition between intervention participants was motivating, others, especially women, felt it may cause pressure and, as such, was inappropriate for a pregnancy app.

6.4.2.10 Theme 10 (Style): Reward Us

All participants felt that virtual rewards in the form of fun graphics illustrating an individual's progress were important. A small minority, particularly men, suggested that rewards should be tangible in the real-world, in the form of vouchers towards baby equipment or discounts on life insurance policies.

6.4.2.11 Theme 11 (Style): Make It Personal

Participants were very keen for the user experience to be as tailored and personal as possible, particularly with respect to feedback. Messages of congratulations, support and motivation were expected to be tailored according to an individual's progress. Using a participant's name in messages was generally approved of.

> *I think you need that feedback, I think, either a congratulatory sort of feedback is great because you've done it really, really well…(or) you've done it eighty percent of the time or whatever, here are some ways that you could perhaps make it a bit easier… those extra little tips and pointers would be great. (Female #8)*

6.4.3 Mapping themes to COM-B and TDF

Table 6-2 shows the themes as they map to COM-B and TDF. This table also includes initial ideas for intervention function and BCTs, as identified using the process described in Michie et al's BCW (Michie, Atkins, West, 2014). The process for mapping themes to COM-B and TDF started by identifying what would need to happen in order for behaviour to change. This information was derived from the detail of the themes identified in the analysis and the literature as reported in Chapter 1. Each component needed for behaviour to change was considered in terms of its relevance to the different TDF domains. The procedures described in Michie et al.'s 'Behaviour Change Wheel – A Guide to Designing Interventions' were used to identify intervention functions and link these with potential BCTs (Michie et al., 2014).

Table 6-2: Summary of themes with regards to a couple-based health behaviour intervention in Baby Buddy mapped to COM-B and TDF

COM-B component	TDF domains	Themes	What needs to happen for behaviours to change	Intervention function	Potential BCTs
Psychological capability	Knowledge	Why?	Understand the benefits of healthy diet and physical activity in pregnancy to maternal and foetal health; risks of poor diet/lack of PA; long term benefits to parents and off-spring	Education	Information about health consequences; information about emotional consequences; credible source
		Why?	Understand why partner support is beneficial	Education	Social support
		What?	Understand what a healthy diet and appropriate physical activity is	Education	Information about health consequences; instruction on how to perform a behaviour
	Cognitive skills	How?	Have the knowledge to identify/prepare healthy meals and snacks; perform appropriate activities	Education, training	Instruction on how to perform a behaviour; demonstration of a behaviour; behavioural practice/rehearsal
	Behavioural regulation	How?	Be able to action plan, set goals, self-monitor, overcome problems and respond to feedback	Training, enablement	Goal setting; problem solving; action planning; review behaviour goals; commitment; feedback on behaviour; self-monitoring of behaviour; behavioural practice/rehearsal; behaviour substitution; habit formation; habit reversal
	Memory, attention and decision process	How?	Use push notifications as a reminder to do the behaviour or self-monitor	Enablement	Prompts/cues
Physical capability	Skills	How?	Have the physical skills to prepare healthy meals/snacks and do appropriate exercises	Training	Instruction on how to perform a behaviour; demonstration of a behaviour

COM-B component	TDF domains	Themes	What needs to happen for behaviours to change	Intervention function	Potential BCTs
Social opportunity	Social influences	How?	Have the ability to deal with pressures from friends/family/social and cultural norms	Education, modelling	Problem solving; social comparison; credible source
		Make it shareable	Use support of partner, friends and family to enable behaviour change	Modelling, enablement	Social support
Physical opportunity	Environmental context and resources	How?	Have healthy eating and exercise ideas that fit with users' circumstances/overcome practical barriers such as time, cost, space for exercise	Training	Problem solving; instruction on how to perform a behaviour; demonstration of a behaviour
Reflective motivation	Belief about capabilities	Support us	Have a belief that you are in control and have the ability to improve your diet and exercise	Training, persuasion	Verbal persuasion about capability
	Intentions/ Goals	How?	Have an intentions to make and set goals for making specific dietary and exercise behaviour changes	Training, enablement	Commitment
	Belief about consequences	Why?	Have an understanding that positive changes to diet and exercise will have health benefits for baby and parents	Education, modelling, persuasion	Information about health consequences; information about emotional consequences; comparative imagining of future outcomes
Automatic motivation	Reinforcement	Reward us	Feel motivated to make changes by virtual or real rewards	Incentivisation	Non-specific reward; social reward; self-reward

Note. Categories taken from the Behaviour Change Wheel framework (Michie et al., 2014)

6.5 Discussion

This qualitative study gauged reactions of 30 adults to the rudimentary concept of an app-based antenatal diet and physical activity intervention. It additionally explored participants ideas and expectations for the intervention's design and content. Through a process of deductive thematic analysis, 11 themes were identified, three of which related to intervention content and eight to intervention delivery style. In terms of intervention contents, participants wanted a clear explanation of why they should engage in an intervention to improve their dietary and physical activity behaviours and what was precisely meant by eating well and being active in pregnancy. They also wanted clear guidance as to how to improve their dietary and activity behaviours – the specific changes they would need to make and the process that might lead to success. As far as intervention style was concerned, participants wanted a feature that was fun, interesting and easy to use. Flexibility and personalisation were deemed essential so that users could make the intervention work for them and their particular circumstances. The idea of interaction with other intervention users appealed, although there was no consensus on what intervention content or data should be shareable or with whom it should be shared. Similarly, whilst participants thought that any type of reward for behavioural change would motivate them, there was little agreement on the form these rewards should take, whether they be virtual or tangible and whether a competitive element to achieving them should be included. Finally, participants felt it was important for the intervention tone to be supportive rather than authoritarian.

The implications of these findings are manifold in informing the development of this new intervention. To engage potential users and persuade them to sign up, this digital intervention will need to provide a clear and motivating explanation of its purpose whilst dispelling barriers to participation. Unlike with face-to-face interventions there will be no opportunity to encourage participants through informal persuasive conversation or more formal techniques such as counselling or motivational interviewing. As such it will be crucial to draw on the themes found in this research, as well as the motivations and barriers for participating as a couple identified in the previous study (see 5.4.3) to optimise promotional messages and the onboarding process.

This study provided valuable insight into how best to express this rationale and possibly motivate users. Importantly, focussing on the specific benefits of healthy eating and being active to maternal and foetal health was deemed to be significantly more motivating than generic health benefits of these behaviours. Addressing the negative consequences of excessive GWG provoked a more divisive response. Qualitative studies have previously explored the complex and often contradictory attitudes women have towards weight gain in pregnancy. The BLOOM study, a qualitative investigation into pregnant women's weight-related attitudes and beliefs in the UK (n=19), suggested that the root cause of often conflicting attitudes and beliefs and consequent dietary and physical activity behaviours could be pregnant women's perceptions of their bodies as fragmented into 'my pregnancy' (or 'the bump') and 'me' (Padmanabhan, Summerbell, & Heslehurst, 2015). In Canada, Vanstone et al.'s (2020) qualitative investigation of how pregnant women (n=39) make and enact dietary and physical activity decisions suggests these are largely made in-the-moment and influenced by physical and practical issues rather than a commitment to weight management (Vanstone et al., 2020). It is unclear the extent to which previous interventions to prevent excessive GWG have taken these beliefs and behaviours into account. With many interventions drawing on theories such as Social Cognitive Theory, Control Theory and the Theory of Planned Behaviour, it may be that the subtleties of pregnant women's self-perceptions and behaviour-driving factors have not warranted the attention they deserve in the intervention design process. Clearly, a nuanced and sensitive approach will be required for a self-directed intervention, in order to accommodate these factors and avoid inaccurate assumptions about women's attitudes and motivations leading to inappropriate weight messaging that could act as a barrier to engagement.

Once potential users have signed up to the intervention, the focus will need to switch to maintaining user engagement. In self-directed health interventions dropout rates typically exceed 40% (Meyerowitz-Katz et al., 2020). Amotivation and loss of interest are the most commonly cited causes of abandonment of mhealth apps (Mustafa, Ali, Dhillon, Alkawsi, & Baashar, 2022). Study 2 participants expressed their desire for a feature that was fun and interesting to use, recognising their own experiences of becoming bored with apps. Thus providing regular new content that interests and

entertains users, while also reinforcing their motivations for behaviour change, will be important if this intervention is to succeed.

In their systematic review of the acceptability, engagement and usability of digital services promoting healthy diets and physical activity, Bergevi et al. (2022) concluded that services should be personalised, dynamic, easily manageable, and reliable (Bergevi et al., 2022). Tailoring the content to provide a sense of personalisation was considered an important requirement by participants in this study, in particular in the context of feedback on a user's progress. Messages in Baby Buddy are addressed to users by name, and where users provide a name or nickname for their unborn child, this is also used. This approach will be adopted for intervention messages.

A final important consideration for the development of this intervention is its shareability. Participants had mixed views on with whom they would like to share content as well as the type of content they would want to share. Many participants suggested a social media style online forum for exchanging ideas and tips, although this would require moderation to ensure posts were appropriate which is beyond the capacity of Best Beginnings. The nature and degree of shareability will need to be determined not only by users' expectations and desires but also Baby Buddy functionality and Best Beginnings' resources.

6.5.1 Strengths and limitations

A strength of this study is that the sample reflected those from more disadvantaged backgrounds who represent the primary target audience for this intervention. With open-ended questions and participants freely generating ideas for a feature that would appeal to and work for them, clear direction for intervention development was achieved.

A limitation of this study was that owing to COVID-19 restrictions it had to be conducted online. Two downsides of conducting focus groups online are firstly that the environment cannot be controlled and participants can be distracted by people or things in their home. Secondly, online focus groups limit the moderator's ability to use non-verbal signals to gauge reactions and guide the discussion (Flayelle, Brevers, &

Billieux, 2022) In this instance, in-person workshop style focus groups, where participants are encouraged to work together to generate and explore new ideas, might have resulted in more creative feedback. Further limitations of this study design are discussed in 5.5.1.

6.5.2 Conclusions

Thematic analysis of participants' feedback on the rudimentary concept provided important guidance for the development of this intervention. The three intervention content themes identified indicate the need to provide potential users with a clear explanation of the feature, using motivating concepts and language. The eight intervention style themes illustrate the importance of creating a feature that users will enjoy using and can be tailored to their needs and personal motivations.

Subsequent intervention development

Following the completion of Study 2, I undertook numerous intervention development tasks as described below.

I drafted the Guiding Principles for the intervention development (see Figure 7-1). These are an essential component of the PBA to digital intervention design, as described by Yardley et al (2015). I presented the findings of Study 2 and the draft Guiding Principles to Best Beginnings and Surrey Heartlands CCG project team. The Guiding Principles were approved by both Best Beginnings and the lead stakeholder at Surrey Heartlands CCG.

I wrote the first draft of the onboarding script to the intervention. This 'welcome' script covered the importance of healthy eating and physical activity in general and during pregnancy specifically. It addressed the motivations and barriers to eating well and being active during pregnancy and to engaging in a dietary and physical activity intervention as a couple. Finally, it guided new users through the process of identifying their healthier habit goal and setting up their own first behaviour change step, as informed by the Tiny Habits Method (Fogg, 2020).

I wrote the first draft of bite-size information and motivational messages (initially n= 68). Their content was based on the themes and COM-B analysis emerging from Studies 2a and 2b, in particular the BCTs identified in Study 2b (see Table 6-2). Each message comprised one to two sentences about healthy eating or physical activity and included information about their associated benefits and risks, tips for eating and snacking well and keeping active, as well as specific recipe and exercise ideas. These were designed as a sequence of messages from week 6 gestation through to week 40, term, where relevant, were gestational-age appropriate, for example (e.g. morning sickness and nausea message was week 6). The messages were designed to guide the user throughout the entirety of the intervention program. I identified where additional information was needed and began to draft a table of linked content, determining the format this should take (i.e., choosing between written information, film or diagrammatic).

I emailed the onboarding scripts and bite-size messages to the PPIE members, who reviewed them for acceptability, feasibility and comprehension. I arranged online meetings (n=18) with PPIE members (n=12) individually to discuss their views on the materials and how best to explore them in user research. The PPIE group included individuals with a variety of different lived experience of pregnancy and in some instances experience of supporting and counselling of others during the perinatal period (see 3.3 for details of the PPIE group). Individual PPIE members provided feedback on their own views of the content and, in the case of those providing support and counselling, how this content might be viewed by others, and how to sensitively explore the topics in research. On the basis of this feedback, I re-drafted the scripts and bite-size messages in preparation for the next stage of user research (see 7.2.1.2 and 7.2.1.3). I also used this feedback to create interview topic guides for the qualitive elements of Study 3.

I briefed a brand design consultancy to generate three alternative names, logos and brand designs for the intervention.

I identified and recruited three experts in their fields - Professor Giles Yeo (professor of molecular neuroendocrinology at the University of Cambridge), Dr Chris van Tulleken (an infectious diseases doctor at University College London Hospitals) and Paula Lavandeira-Fernandez (GDM midwife at Surrey Heartlands CCG) to make a series of short healthy eating films for the intervention. I chose the former two as they have written mainstream books about diet and health and have a media presence. I co-created scripts with these individuals and assisted, to varying degrees, in the filming process itself.

I conducted stakeholder interviews with midwives (n=8) to explore their views of the intervention concept and how they would envisage it fitting into established antenatal care pathways in the UK. A summary of the findings from the midwives' interviews can be found in Appendix 11.

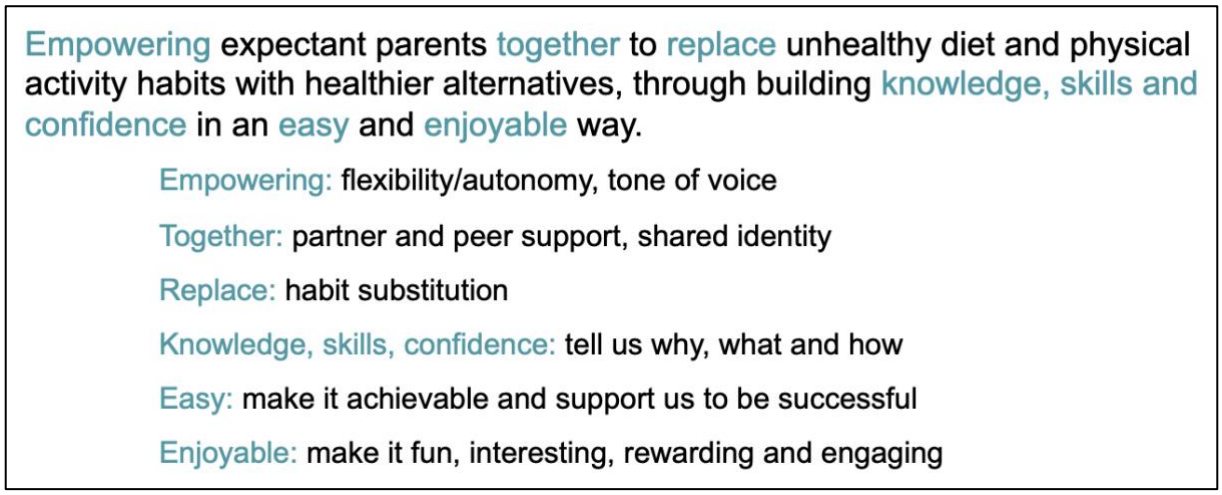
Chapter 7 Study 3: An iterative research study to develop and refine the intervention design, content, tone and branding

This chapter reports on the findings of Study 3, a qualitative study comprising online couple and individual interviews with expectant parents and parents of a baby of up to 18 months old. The aim of this study was to explore responses to the detailed intervention design and identify amendments and improvements to the design, content, tone and branding. The results of Study 3 helped me to fine-tune the overall intervention design, in particular the on-boarding process, goal setting feature and the weekly messages.

7.1 Introduction

The PBA to health intervention development requires a set of Guiding Principles to be established to focus attention on what is needed to make the intervention acceptable, feasible and engaging. The Guiding Principles summarise the intervention goals and how these might be achieved. They draw on a deep understanding of the target user and how the intervention can be engaging, enjoyable, meaningful and persuasive for the target user. Whilst the Guiding Principles act as a specification for the intervention, they are not fixed and can be revisited and refined during the development process. Based on the findings from Studies 2a and 2b, the Guiding Principles underlying the development of this intervention were formulated and agreed with Best Beginnings. These are summarised in Figure 7-1.

Figure 7-1: Guiding Principles for the development of the intervention



The Guiding Principles reflect three key directional changes that were made because of the findings derived from Studies 1, 2a and 2b and the collective input from the PPIE group:

1. GWG would no longer be focused on as an overt goal or explicitly addressed within the intervention. Given the resistance voiced by participants in Study 2b and the input from the PPIE members with lived experience of being a pregnant women living with obesity and/or experience of supporting other women living with obesity through pregnancy, it was felt that a focus on GWG might alienate potential participants whose risk of adverse health outcomes from poor dietary and physical activities in pregnancy was greatest. Focusing rather on improving the behaviours that might lead to healthy GWG was deemed to be a potentially more successful, inclusive and less stigmatizing route. This covert approach was supported by Best Beginnings' belief in the power of 'health by stealth'. Moreover, the Surrey Heartlands CCG midwife steering group responded positively to this decision, knowing the reluctance of midwives to broach the subject of patient weight with pregnant women in the clinical context.

2. The intervention would target expectant couples rather than pregnant women alone. The potential benefits of this approach to intervention users are summarised in Study 2a. Moreover, this approach was deemed to fit well with Baby Buddy given the newly developed fathers' and co-parents' pathway. It was agreed with Best

Beginnings that a single user version would also be designed to meet the needs of pregnant women without a partner or those who preferred not to include their partner in the intervention. This approach would maximize inclusivity.

3. The intervention would be designed to encourage the development of new, lasting habits for life rather than focus on short-lived behaviour change exclusively during pregnancy. Not only was this felt to be more consistent with the healthier behaviours rather than GWG approach, but also it could create a starting point for further health interventions targeting postnatal Baby Buddy users.

Using the Guiding Principles as the framework, a detailed intervention concept was developed in conjunction with Best Beginnings (see 7.2 for a description of the intervention concept).

The aim of Study 3 was to explore reactions to the fully developed intervention concept, including the onboarding process, the key goal setting, self-monitoring and feedback features, examples of the weekly messages and branding ideas. A further aim of this study was to ensure the intervention design and content was culturally sensitive and inclusive. Whilst this topic was discussed with all participants, a sub-study was embedded within this study, focussing on British Asian communities, as the largest minority ethnic group in the UK. This was designed as an MSc Health Psychology project, which I supervised. The key findings from this sub-study are included in this chapter and a more detailed summary of themes can be found in Appendix 10.

7.2 Method

7.2.1 Overview

The process of designing this intervention was iterative and collaborative, in line with best participatory intervention design principles. Throughout the whole project meetings were held with Best Beginnings. During this phase of research regular weekly meetings took place to ensure the intervention design remained aligned with Best Beginnings' objectives, evidence-based approach and feasibility criteria. A wider

multidisciplinary team (n=14) including academic researchers, dieticians, perinatal fitness instructors, healthcare professionals provided ad hoc guidance on the breadth, accuracy and tone of the dietary and physical activity information. In addition, two app design consultancies and a brand consultant were engaged at this stage by Best Beginnings to advise on design of the user interface, branding and logo.

The PPIE group (see 3.3) provided input into the design of this research study, reviewing the recruitment criteria, topic guides, stimulus materials and giving guidance interviewing style for exploring sensitive issues. The PPIE group also contributed views on the intervention design, both from a personal standpoint and, where relevant, in the context of their role as a coach or support worker.

7.2.1.1 The intervention concept

The intervention concept was informed by theory (COM-B, TDF and Fogg) and built around the key interactive features of goal setting, self-monitoring and feedback. Alongside this, a series of bite-size messages, films, recipes and tips was created in order to incorporate some of the other relevant BCTs identified in the COM-B analysis (Studies 2a and 2b).

7.2.1.2 Onboarding procedure

An onboarding script was written to introduce new users to the intervention, to communicate the importance of healthy eating and physical activity during pregnancy and to guide users through the process of setting up their healthier habit goals and the first behaviour change steps. It built on the motivations and barriers both to eating well and being active during pregnancy as identified in the literature (see 1.5), and to engaging in a dietary and physical activity intervention as a couple as identified in Study 2a (see 5.4.3). The full onboarding script can be found in Appendix 6. The onboarding process was envisaged as a series of short, animated films and script was written as a series of frames. The process of choosing healthier habit goal(s) and behaviour change step(s) was based on Fogg's Tiny Habits approach, whereby a user is encouraged to work through various exercises to identify a goal that they are motivated to work towards and then to find the first, tiniest change in behaviour leading towards this goal that is likely to be achievable to them (Fogg, 2020).

7.2.1.3 User experience

Once onboarded, users are able to add and amend their goals, set up reminders to perform their behaviour (or baby step), record their behaviour, log their feelings, thoughts and photos and receive feedback on their progress. Examples of how users can record their behaviour changes and track their progress were mocked up in wireframes for the research (see Appendix 7).

Users will also commence an up to 34-week programme of gestational age-appropriate bite-size messages covering dietary and physical activity information, fun facts, tips, recipe ideas and challenges (see Appendix 8). This content was created with the input of the team of experts and tested with the PPIE group and other stakeholders prior to this stage of research. Input from Best Beginnings' script writer helped ensure that all content conformed to the voice of Baby Buddy and were consistent with a reading age of 9 years old.

7.2.1.4 Branding ideas

Three alternative branding ideas were created by a brand consultancy Studio Baum – Baby Steps, Healthier Habits (initially presented as Healthier Homes) and Groove (see Appendix 9).

7.2.2 Study design

Given the uncertainty around the feasibility of conducting face-to-face research during the COVID-19 pandemic, Study 3 was designed from the outset as online research. Since Study 2a had indicated potential for engaging couples in this intervention, a decision was made to conduct a mix of couple and individual interviews. These were conducted on the video conferencing platform Zoom.

As an iterative study, fieldwork took place in three phases over a 6-month period (December 2021 to May 2022). Throughout this period stimulus materials were updated regularly to incorporate changes made to the intervention content, design, tone and branding. A fourth phase of interviews took place between May and August 2022 focussing specifically on ensuring cultural inclusivity for users from British South

Asian communities. These interviews were conducted by UCL Health Psychology MSc student Arya Pimprikar (AP).

7.2.3 Participants

Participants were either expectant parents in the last trimester of pregnancy or parents of a baby under 18 months old. Consistent with Best Beginnings' policy of addressing health inequalities, most participants were drawn from economically or socially disadvantaged communities, including those without tertiary education, on low incomes and from minority ethnic groups. In addition, recruitment screening questions were used to exclude those who scored themselves a 7 or over for healthy eating and keeping fit where 10 was excellent and 0 very poor. This ensured that the sample comprised those who would benefit most from the intervention rather than those already predisposed to be engaging in healthier lifestyle habits.

The final sample size was determined by the data saturation method – once no new data and insight were being uncovered in the interviews, the interview process was deemed completed (Saunders et al., 2018).

7.2.4 Recruitment procedure

Recognising the challenge of recruiting minority ethnic groups and low-income participants to qualitative research, an a priori decision was made to use professional market research recruitment services, Apogee Group Recruitment, to assist with recruitment. Additional participants were recruited through social media. Participants received an incentive of £25 per individual interview or £40 per couple interview.

7.2.5 Topic guide

Topic guides were designed for couples and individuals using a flexible structure and open-ended questions to allow participants to comment on and generate ideas for the aspects of the intervention of most interest and concern to them. The moderators (AR and AP) ensured that the core topic areas were covered in each session.

A initial version topic guide can be found in Appendix 5. As an iterative research study, the topic guide evolved over the course of the research, although its broad structure and content remained constant.

7.2.6 Stimulus materials

Two to three days before each interview, participants were emailed the onboarding script, examples of the wireframes illustrating the user interface and an extract of approximately 4 weeks of bite-size messages (see Appendices 6 - 8). For couple interviews, a partner version of the onboarding script was also sent. In the email, participants were instructed to look through these documents in advance of the interview and write down any comments to act as a memory jogger during the interview. At the start of the interview participants were asked to describe the new feature as if they were explaining it to a friend in order that their comprehension of the feature could be assessed. If there were any areas of confusion or misunderstanding, the source of these was identified, and misunderstandings were rectified before the interview proceeded.

During the interviews the moderator shared their screen to show participants the remaining wireframes illustrating the goal setting and self-monitoring functions and branding options with alternative names and designs (see Appendices 7 and 9). Some participants were also shown additional bite-size content messages when time allowed.

7.2.7 Data analysis

An iterative approach to data analysis was adopted with feedback from early interviews resulting in changes to the intervention which were tested out in later interviews. Notes were taken during each interview. The moderators listened to the interview recording immediately or soon after the interview and additional notes were made and verbatims transcribed. AR and AP also listened to a sample of each other's interviews. Consistent with the PBA, a 'Table of Changes' (Bradbury, Morton, Band, van Woezik, et al., 2018) was used to systematically record proposed and actual changes to the intervention delivery and content. All positive and negative comments

that might impact the intervention design were logged immediately after each interview and corresponding suggestions for changes were discussed and agreed on by AR and AP and, when necessary, with Best Beginnings. The MoSoCoW project classification system (MUST have, SHOULD have, COULD have, WOULD like to have) was used to rank the importance of the proposed changes (Clegg & Barker, 1994). 'MUST have' is defined as those requirements critical to the success of the intervention, with the degree of importance diminishing through to 'WOULD like to have'. A further level of coding was used to record why the proposed changes were important. The categories used were 'important for behaviour change'; 'easy and uncontroversial'; 'repeatedly reported'; supported by experience'; 'does not contradict the literature, experience or Guiding Principles' and 'not changed'. The comments classified as 'MUST have' and 'SHOULD have' that involved changes to functionality or diverged from the Guiding Principles were discussed with Best Beginnings and led to immediate changes to the intervention design and stimulus materials where possible. The comments classified as 'COULD have' and 'WOULD like to have' were also discussed with Best Beginnings and joint decisions were made as to their feasibility and necessity.

Thematic analysis was used to explore the qualitative data in the sub-study investigating the views of British South Asian expectant parents towards the concept of a digital dietary and physical activity intervention. See Appendix 10 for a summary of the themes.

7.2.8 Ethics

Approval for this stage of research was granted by University College London Research Ethics Committee (16749/002). Participants provided informed consent online via REDCap in UCL's Data Safe Haven and their consent to be audio recorded was reconfirmed before the interview commenced.

7.3 Results

Overall, 34 participants took part in Study 3 either in individual interviews (n=20) or couple interviews (n=14). Interviews were between 40 and 60 minutes long. Of these,

9 were recruited for the sub-study focussing on understanding the acceptability of the intervention by British South Asian expectant parents.

7.3.1 Characteristics of study participants

Participant characteristics are summarised in Table 7-1. Participants were aged between 22 and 43 years. Over three quarters of the sample (82%, n=28) were of non-white ethnicity and 40% (n=13) had no education beyond secondary school. The majority of the sample were first time parents or expectant parents `(n=22). Three participants were single parents. Whilst efforts were made to recruit parents in same sex relationships, all interviews were with heterosexual couples.

Table 7-1: Characteristics of study participants

	Female n=26	Male n=8	Total n=34
Individual interview	19	1	20
Couple interview	7	7	14
Age (years)			
<20	0	0	0
20-29	12	4	16
30-39	13	4	17
40+	1	0	1
Ethnicity			
White	5	1	6
Black	8	3	11
Asian	10	4	14
Mixed	3	0	3
Education			
None	1	0	1
GCSE	3	1	4
A level	5	3	8
Graduate	10	3	13
Post-graduate	5	0	5
Not stated	2	1	2
Pregnancy/baby status			
First pregnancy/baby	16	6	22
Second+ pregnancy/baby	10	2	12
Pregnant	8*	4*	12
Baby < 6 months	5	4	9
Baby 6-12 months	10*	1*	11
Baby 13-18 months	4	0	4

Note. * One couple had a baby of 12 months old and were expecting their second

7.3.2 Table of Changes

As explained in 7.2.7, a Table of Changes was used to record participants' responses and identify changes that needed to be made to the intervention design, tone and

content. A Table of Changes is a working document, akin to a 'To Do' list where items are added and removed as they are dealt with. An example of it can be found in Appendix 12. The following sections summarise the overall themes that arose from the Table of Changes analysis and response to the specific aspects of the intervention design, content and branding that were explored in this stage of research.

7.3.3 Response to the overall concept and key learnings

Response to the overall concept of a feature within Baby Buddy to encourage and support expectant couples to develop healthier dietary and physical activity habits was generally very positive. Participants' views were consistent with those expressed in Studies 2a and 2b. In addition to the feedback on specific aspects of the intervention, a number of important general learning emerged from this research:

7.3.3.1 Pregnancy specific

Participants thought it important that the content of this feature was specific to pregnancy rather than general guidance on healthy eating and being active. There were several reasons for this. Firstly, participants identified that the needs and circumstances of pregnant women were different from those of the general population and wanted these to be acknowledged in the feature. Certain foods (e.g. unpasteurised soft cheese and raw shellfish) needed to be avoided and certain types of exercise were considered high risk (e.g. contact sports). Pregnant women also had to cope with nausea, vomiting, extreme fatigue and other conditions affecting diet and activity levels. Secondly, participants felt that pregnancy specific content would reassure users that advise was appropriate and safe to follow at this important time. Thirdly pregnancy specific information was thought to be lacking whereas general advice on healthy eating and keeping active was considered to be abundant.

> *We've heard the general stuff since we were children and haven't done it – the only way we will now is if it's for baby. (Female #11)*

7.3.3.2 Health not weight

Consistent with Study 2b findings, participants, especially those living with obesity and/or experience of an eating disorder or disordered eating, disliked the idea of the

feature focussing on weight messages. Indeed, many felt this would be a barrier to engagement.

> *They don't weigh you now as it's detrimental to mental health. You don't want any pressure or stigmatism* (stigma) *about gaining or losing weight. (Female #10)*

> *The reality is a lot of women put on weight during pregnancy. Our bodies are not all the same…you need to know but if you're made to feel guilty, I think you'd just give up. (Female #2)*

This strong resistance to weight messages was evident in the response to the onboarding script, which mentioned the risks of gaining an unhealthy amount of weight, and the response to the bite-size messages, which included a message about weight gain in pregnancy and postpartum weight retention (See Appendix 8).

Focussing on the importance of and how to eat a high-quality diet and stay active for a healthy pregnancy and a healthy baby was considered significantly more motivating. Moreover, the message had greater credibility as most participants believed the notion that maternal diet, more readily than GWG, might influence foetal health.

> *I like food and I like unhealthy food….but if it said 'be your best for your baby'… (Female #4)*

7.3.3.3 Terminology and tone

An important learning was that 'healthy eating' was not always considered to be an appealing or motivating term to describe a goal of this feature, because of both its ubiquity and its association with expensive ingredients.

> *Healthy eating you think of expensive things – like organic…smoothies and salads with exotic vegetables. (Female #1)*

Whilst 'healthy/healthier' was considered acceptable in the context of choices and swaps, 'nutritious foods' or 'foods full of important nutrients' appeared to be more motivating terms to use generally in the feature. Moreover, these terms reinforced the

notion of a pregnancy and foetal health specific feature rather than a general healthy lifestyle feature.

> *Healthy eating is for everyone. I'd expect this to be about what is good to eat when you're pregnant – what's right for the baby. (Female # 23)*

Other useful insights into appropriate terminology and tone arose, for instance with regards to the terminology of the target users:

> *If you say 'mums' it's like you're coming alongside us. If you say 'mothers' it's like you're telling us to do something. (Female #11)*

7.3.3.4 Personal and flexible

'Give us flexibility' and 'make it personal' were two of the themes that were identified from the qualitative interviews in Study 2b. Feedback from Study 3 reinforced the importance of these two themes. Participants were keen that the feature could be tailored to suit their individual needs. They wanted to be able to choose their own healthier habits to work on; decide whether to involve their partner or another person; select whether or not to receive notifications and set up their own schedule of reminders, baby steps and feedback on progress. This degree of flexibility and personalisation was deemed important to make the program work for all its users, regardless of their needs, priorities and circumstances.

> *"It's adapted for me – where I have done well and where I can improve. I couldn't be as active as I wanted to. I had to have a lot of bed rest, but with this it wouldn't matter." (Female #8)*

> *"It didn't say 'you must do this' - it was 'what sort of goals do you want to set' which is so much better. I got GDM diagnosed at 8 weeks and I ended up with pelvic girdle pain, but I still would have done this." (Female #10)*

7.3.4 Response to the onboarding scripts

Copies of the first version of the onboarding scripts for women and their partners can be found in Appendix 6. These scripts went through several iterations during this study. Key learnings were as follows:

7.3.4.1 Proximal not distal health benefits

Focussing on the current health benefits to mother and baby of developing healthier habits was found to be significantly more motivating than promising future health benefits. Most participants showed little interest in the increased risk of later life cancers or heart disease as a consequence of unhealthy behaviours. In contrast, messages about the effect of healthier behaviours on foetal development and maternal well-being in pregnancy were highly motivating.

> *Nobody wants to hear about the negative things – like you're gonna get cancer. Tell us the positive things like if you do this you'll have more energy and feel better now – that's what matters to me - how I feel now, not what might happen in 30 years' time. (Female #6)*

> *We are all going to die of something – I want to know about feeling good now – good for your energy, mentally brighter (Female #4)*

7.3.4.2 Empathy and understanding

Showing empathy and understanding of the challenges facing pregnant women was appreciated and expected to help draw in potential users. Participants frequently spontaneously commented on examples in the script of empathy and understanding. They found this approach to be reassuring, suggesting a feature that would help and support them in their efforts to develop healthier habits, rather than instruct and berate them when they missed their targets.

> *I like that it understands – you can get all hormonal and feel like an absolute failure. (Female #11)*

7.3.4.3 Not just first timers

The feature was thought to have relevance and appeal to multiparous women, and they wanted to feel more included. Several of the participants with one or more baby noted that the early versions of the onboarding script seemed to speak to first time expectant parents rather than those who already had a child/children. These participants saw this feature to be as relevant to them as to first time expectant parents. Indeed, some reported that their health behaviours in their first pregnancy had deteriorated and they were determined that this should not be the case on subsequent pregnancies.

> *I've had a child before, but I still ask these questions. (Female #2)*
>
> *The first time round you don't realise what you are doing. The second and third times you know what you want (Female #3)*

7.3.4.4 No quizzes

The quizzes at the end of each onboarding section were disliked. Whilst they recognised the value of the quiz in summing up the main messages and the interactivity could appeal, most participants rejected quizzes as either unnecessary or time-consuming. Participants also felt quizzes could be patronising, especially if the answers were obvious.

7.3.4.5 Keep it quick and simple

Users want to set their own pace for onboarding. The initial onboarding script was designed to be delivered over a 3-4 day period, with potential users having tasks to do at the end of each day. Most participants felt this would draw out the onboarding process unnecessarily and some thought that they might even quit as a result.

Overall feedback suggested that the onboarding process needed to be straightforward and quick to complete to avoid potential users giving up. Participants were quick to pick out potential points in the onboarding process where they felt too much effort was required and they might have given up. There was some resistance to the instruction to draw a picture or write a description or find some photos to capture their goal. Indeed

several participants felt that the exercises to identify their habits and first baby steps would be too time consuming and suggested that lists of these should be provided for users to select from.

7.3.5 Response to the bite-size messages

Participants responded very positively to both the concept and the proposed content of the bite-size messages. However, there were mixed views on how frequently messages should be received. Whilst many participants liked the idea of being alerted to a new message every day (which is consistent with the 'daily information' messages received by Baby Buddy users currently) and felt this would help to keep their interest levels high, others thought every day might be too frequent. However, once participants were informed that they would be able to switch off notifications and access these bite-size messages in their daily feed at their own leisure, fears about too many messages were assuaged.

> *A weekly challenge would be a bit of fun. (Female #6)*
>
> *May be not every day but a few times a week would be good. (Female #9)*
>
> *I like little notifications that pop up on my phone during the day. (Female #5)*

Of particular concern to participants was the length of the messages, some of which were deemed to be too long. Acknowledging short attention spans and familiarity with social media length copy, most participants wanted all messages to be very short, comprising a single idea or piece of information.

> *I get bored of reading. (Female #5)*

Tonally, messages that were positively framed and gave participants ideas and tips for how to improve their health behaviours were more appealing than those that focussed on the risks of and discouraged poor dietary and physical activity behaviours.

Novel messages, such as the number of teaspoons of sugar in a squirt of tomato ketchup and information about the gut microbiome, were particularly appealing. The idea that these messages provided links to recipe ideas, films or more information on a particular topic was appealing and thought to cater well for the different levels of interest users were likely to have.

> *It's good that you can find out more if you want to. Not everyone might want to, but I'm interested in the science behind things – I want to know more (Female #1)*

Inclusivity was also an important issue with regards to the bite-size messages. Participants expected dietary-related messages to cater for vegans and vegetarians and to reflect cultural culinary diversity. Similarly, physical activity messages were expected to cater for different capabilities and levels of fitness.

One participant who had an eating disorder felt messages needed to be phrased carefully to minimise the risk of triggering disordered eating. To ensure this was the case, all messages were reviewed by a psychologist practitioner and academic researcher who was an eating disorders specialist.

7.3.6 Response to the Baby Steps name and design

Three alternative names were considered at this stage of research – Baby Steps, Healthier Habits (initially presented as Healthier Homes) and Groove. Participants were also encouraged to suggest other options. The Baby Steps name was widely preferred and generally thought to be a suitable and appealing name for the feature. Despite some reservations from the PPIE group that Baby Steps was patronising and cliched, participants consistently responded positively to the Baby Steps name. Not only was it felt to be fitting for a pregnancy feature, but also is worked well to explain the method of building new habits through small changes. Of the three different brand designs shown to participants (see Appendix 9), the little feet Baby Steps design was consistently preferred.

> *The name (Baby Steps) makes it feel not so daunting. (Female #4)*

Not 'Healthy Homes' – it sounds very NHS (Male #7)

7.3.7 Ensuring cultural sensitivity and inclusivity

Participants from racial and ethnic minority groups reported that the most obvious way of communicating that the intervention was for everyone, including them, was by including images of expectant parents and babies from a wide range of communities.

> *… showcasing different women and different sizes (Female #2)*
>
> *Do you have something like with a lady with a hijab or anything? It's good if you do. (Female #21)*

Including ethnically diverse recipe and snack ideas was also seen as an important way of demonstrating cultural inclusivity.

> *If it's coming from Jamie Oliver I'm going to go nah, I'll skip that one. But if it's coming from an Indian chef, I am more likely to think they know what they are talking about. (Female #24)*
>
> *We use a lot of coconut oil – olive oil isn't really a thing for us (Female #22)*
>
> *We have very spicy food* (in Eritrea) – *so it'd be nice to have some spicy recipes (Female #3)*

Participants wanted the intervention to address culturally specific issues like festivals and fasting and beliefs/myths about diet in pregnancy, such as certain foods causing miscarriage.

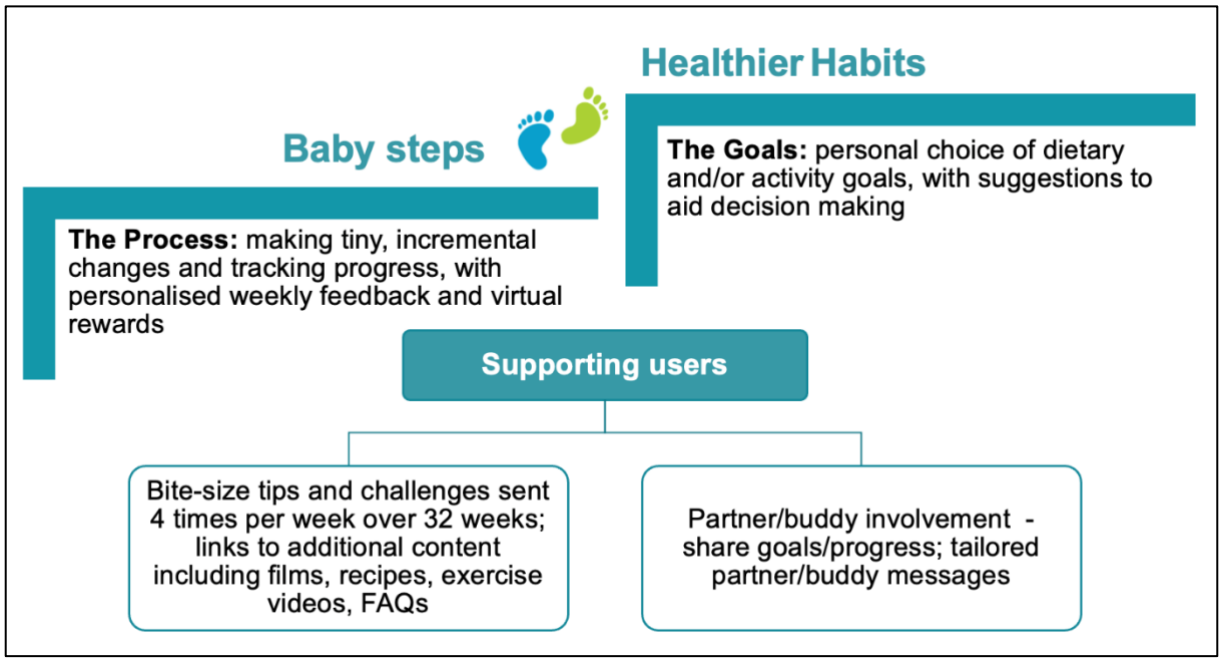
> *(I was) not encouraged to eat pineapple during pregnancy, so I was like okay I'll avoid it … although it doesn't have robust clinical evidence there's no harm in me not eating it …and if something did happen to the baby I would attribute it to this random pineapple that didn't really have much to do with it (Female #25)*
>
> *Diwali was a big one, because prepping the food and also the type of food we eat... it all the kind of 'naughty things isn't it... like snacks,*

and it's all fried food and that kind of thing... it would be nice to see if there was a section on world festivals (Female #20)

7.3.8 Summary

The final concept design emerging from this iterative research study is summarised in Figure 7-2.

Figure 7-2: Summary of the BaSHH intervention design and branding emerging from Study 3



7.4 Discussion

This qualitative research study of 34 adults explored user-response to the idea of a couples' intervention targeting dietary and activity behaviours in pregnancy. A wide portfolio of different aspects of the intervention feature were explored through an onboarding script, examples of the proposed bite-size messages and three options for brand name and design. Whilst overall response to the intervention concept was positive, participants provided important feedback on its content and tone.

The results from the present study reinforced findings from Study 2b that weight messaging could be act as a deterrent to potential users. With the agreement of Best Beginnings and endorsement from Surrey Heartlands CCG a decision was made to

exclude all references to weight gain in the onboarding and bite-size messages. Although the logic of this 'covert approach is clear, it is not consistent with many published interventions targeting GWG (Craemer et al., 2019). Whether an intervention promoting healthy eating and keeping active without weight messaging can change behaviour sufficiently to effect GWG will only be determined by an RCT evaluation of this intervention.

The idea of regular bite-size messages containing information, tips, recipe and snack ideas and activity suggestions received an enthusiastic response. Whilst the practical benefits of this information to users is obvious, these messages could potentially play an equally important role in maintaining user-engagement. Rates of drop-out from digital interventions have been reported to be around 43% (95%CI: 29,57), (Meyerowitz-Katz et al., 2020). Few intervention studies report on reasons for drop-out. However, those that have, and studies investigating why users abandon commercial health apps, suggest boredom and loss of novelty to be contributory factors (Krebs & Duncan, 2015; Mustafa et al., 2022). Baby Buddy's daily information, which is a similarly bite-size message that appears in users' feeds at 10am every morning, is consistently the most highly rated feature of the app (Best Beginnings' management data), being praised for its useful, accessible and timely content. The challenge for this intervention is to ensure that its bite-size messages are as relevant and appealing to users.

This study provided important feedback on the need for a simple onboarding process that can be completed at a pace determined by the user. Resistance to the proposed quizzes and interactive exercises meant deviating from Fogg's Tiny Habits method of identifying habits to work on and the first steps to take (Fogg, 2020). As a self-directed intervention, identifying and avoiding potential barriers to engagement is of paramount importance. Consequently, the decision was taken to be guided by the user research rather than adhere rigidly to the theory and provide users with suggested baby steps. A similar approach was used successfully in a study to improve self-reported gratitude (Hollingsworth & Redden, 2022).

The study also drew attention to the importance of being culturally sensitive and inclusive and suggested ways in which this can be achieved. The UK is an ethnically

and culturally diverse country and reflecting this diversity in the intervention was identified as a priority if it is to be delivered and effective at a population level. The Born in Bradford study, a longitudinal birth cohort study of women recruited when pregnant between 2007 and 2010 (n=11,445) exploring the impact of environmental, psychological and genetic factors on maternal and child health, has highlighted stark differences between the city's bi-ethnic population (42% White/White British and 52% Asian/British Asian), including in antenatal health risks (e.g. maternal obesity) and health behaviours (e.g. levels of activity) (Collings et al., 2020; Cooper, Petherick, & Wright, 2013; Marvin-Dowle & Soltani, 2023). A systematic review of 51 qualitative and mixed methods studies exploring migrant women's experiences of pregnancy, childbirth and maternity care in European countries concluded that maternity care needs to beyond clinical care and address migrant women's unique socioeconomic and psychosocial needs (Fair et al., 2020). Similarly the Nurture early for Optimum Nutrition programme, an intervention targeting infant feeding and care in the UK British Bangladeshi community, recommended interventions be co-developed with communities and tailored to take account of social and cultural norms (Lakhanpaul et al., 2020).

7.4.1 Strengths and limitations

A strength of this study was that the sample was ethnically and demographically diverse, providing novel insight into the needs and wants of more marginalized communities in the UK with regards to antenatal care and health behaviours. Moreover, the inclusion of couples' interviews provided an additional dimension to the exploration of the intervention design and content, allowing insight into the couple dynamic and decision-making process regarding dietary and activity behaviours. However, a limitation of the research was the potential for self-selection bias in the sample. Participants were pre-informed about the topic of discussion. As such there was risk that participants were more open to the concept of a healthy eating and physical activity intervention than a truly random sample might have been. An attempt to mitigate this involved screening out potential participants who rated themselves highly on healthy eating and keeping fit. Social desirability bias could also have led to participants projecting a higher level of interest in healthy lifestyle behaviours and behaviour change than might normally be the case. A further limitation of qualitative

research methods in general, is the influence of the researcher in both moderating the sessions and interpreting the findings. In this study two moderators discussed the findings of the interviews at length, challenging each other's interpretations. Moreover, discussions with the PPIE members before and after the fieldwork helped to provide yet another perspective on the findings, and contextualised results.

7.4.2 Conclusions

Study 3 reinforced the appeal and acceptability of an intervention for expectant couples targeting dietary and physical activity behaviours. Response to GWG messages in both the onboarding script and the bite-size messages indicated that weight messaging could act as a deterrent to engagement and as such a decision to minimise if not exclude references to GWG. The research provided valuable feedback on elements of the onboarding process that could result in potential users discontinuing and identified terminology that was off-putting or unmotivating. Finally the research identified a preferred brand name and design.

Subsequent intervention development

Throughout Study 3 and upon completion, I undertook a number of intervention development tasks to action the new insights derived from the study into the BaSHH intervention prototype. These are described below.

I wrote a task brief for an app design company (Resonate) and organised a series of meetings with this company and Matt Black, head of digital at Best Beginnings, to translate my ideas for the intervention into a digital user interface and user journey that was consistent with Baby Buddy's style and tone.

I updated the intervention design based on the findings of Study 3. This included revising the onboarding process and editing the script in line with (see 8.3); devising and scripting the pre-set health goals, baby steps and behaviour trigger messages (see 8.3) and rewriting many of the existing intervention bite-size messages and adding new ones (n=128) (see 8.10). In line with Study 3 findings, messages were framed positively, and their format was re-structured to include a 'top tip'. I reviewed the new messages with some of my PPIE members and Dr Becky Richards, a psychologist practitioner and academic researcher with experience in eating disorders. I worked closely with Dr Jenny McLeish, the Baby Buddy writer, to ensure the content was in the Baby Buddy voice.

I also wrote a set of 32 partner messages, scripted for expectant dads/same sex parents and non-parent buddies that were essential to guide participants along the partner intervention journey.

For the goal setting element of the BaSHH intervention, I wrote a series of motivational feedback messages (n=14) and reviewed these with two psychotherapists (see 8.12).

I began collating affordable and pregnancy-suitable recipe and snack ideas and exercise videos to include in the intervention. As part of this exercise, I identified and met with organisations and individuals such as Diabetes UK, The Food Foundation, The Active Pregnancy Foundation and Dr Rupy Aujla ('The Doctor's Kitchen' - a

wellbeing and nutrition website and app) to discuss embedding their content in Baby Buddy or linking to it.

I updated the linked content relating to the bite-size messages, identifying where existing Baby Buddy content could be used and where new content was needed. I drafted the new content and worked with Dr Jenny McLeish to ensure the language and tone was appropriate for Baby Buddy.

I identified a potential funder, wrote a funding application and secured funds for building the new interactive features (goal setting, self-monitoring and feedback) that we were proposing to include in the intervention.

Chapter 8 Baby Steps to Healthier Habits intervention design

This chapter provides a detailed description of the complete BaSHH design arising from the previous stages of user research and developmental work.

8.1 From fully researched intervention concept to finalised intervention design

Baby Steps to Healthier Habits (BaSHH) is designed to span the entirety of pregnancy, from as early as 6 weeks gestation to term. The program consists of a defined onboarding stage during which users determine their healthier habit goals and self-select or self-design their first behaviour changes or baby steps. Throughout the week-by-week programme users are reminded to make and record their baby steps and weekly feedback gives them a progress report on based on their self-recorded baby steps. Users receive bite-size messages 4 times each week comprising dietary and physical activity information and tips, as well as recipe and snack ideas and activity ideas and exercise videos. Given that the intervention will be embedded within an established health app (Baby Buddy 2.0) it was essential that it was designed such that it could be seamlessly integrated into this pre-existing delivery and hosting platform. Accordingly, a brief was written for Best Beginnings' existing app designers and several meetings took place with this team over a 3-month period during which designs were reviewed and refined in Figma, a sophisticated and interactive web application for interface design ("Figma: the collaborative interface design tool.," 2023).

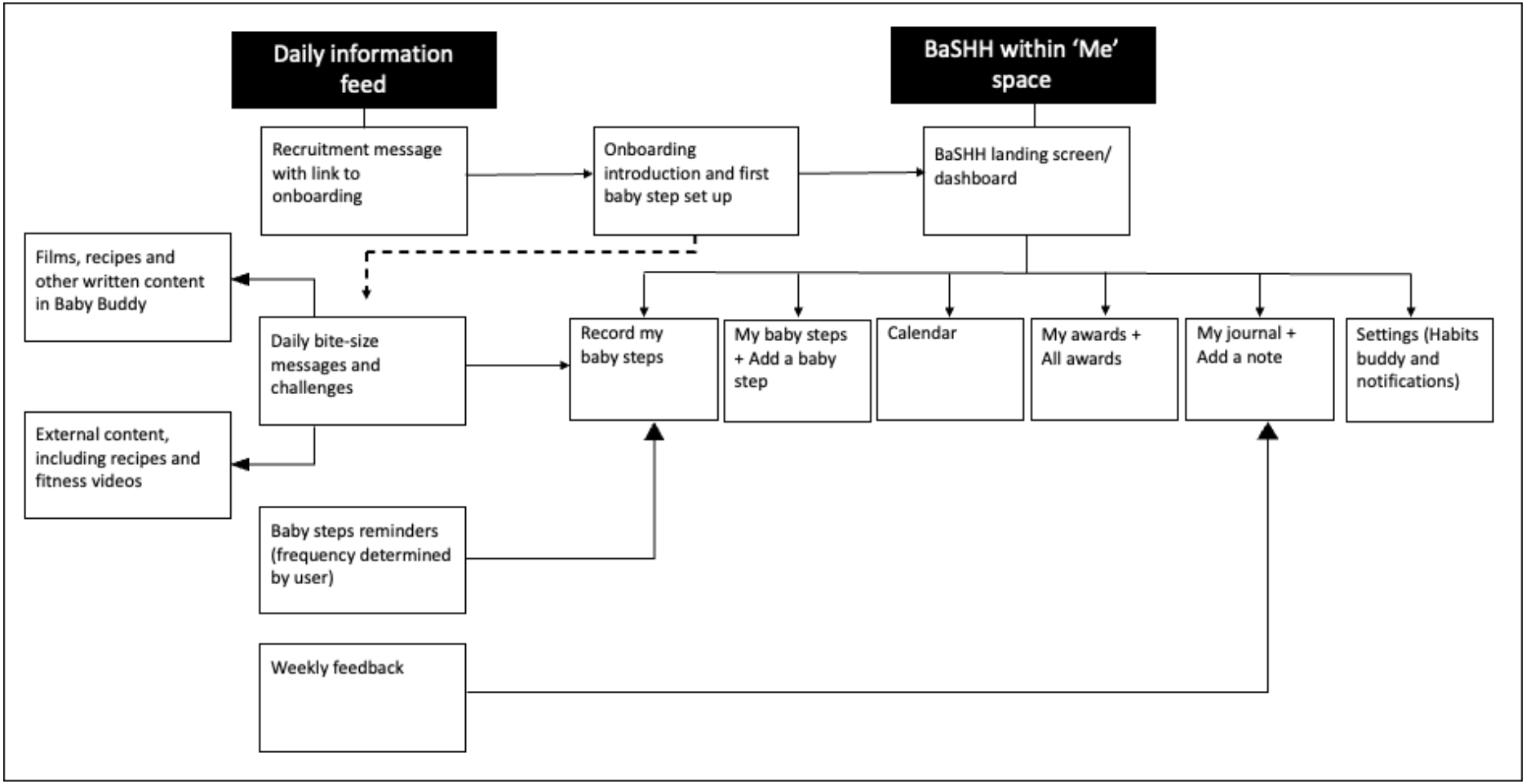
Whilst the name Baby Steps had received a positive response in Study 3, for copyright reasons, it was not available. Hence the name Baby Steps to Healthier Habits (BaSHH) was chosen. Within the app prototype the shortened version of Healthier Habits preceded by the little feet logo (signifying baby steps) was used (see Figure 8-2). The term baby steps was used to describe the behaviour changes that users choose to make.

Best Beginnings decided that a new colour should be introduced to the Baby Buddy palette to distinguish BaSHH content from regular, existing Baby Buddy content. All

BaSHH messages in users' daily are in dark purple. They also carry the BaSHH logo as illustrated in the top left-hand corner of the example messages in Figure 8-2.

Figure 8-1 illustrates the structure of the final intervention design. This diagram shows the different features of BaSHH and where within Baby Buddy they are accessed. The invitation to set up BaSHH (onboard) appears in a newly registered user's feed (pregnant users only). This links to the onboarding process through which users create their BaSHH dashboard. The BaSHH dashboard is accessed via the 'Me' space within Baby Buddy. Here users can create, add and record baby steps, as well as see their awards, change their settings, access their calendar and add to their journal. Feedback on the user's progress is added to this space each week. The bite-size messages and challenges appear within the user's daily information feed. All BaSHH messages are coloured purple to distinguish them from general Baby Buddy messages. Each element of this structure is described below.

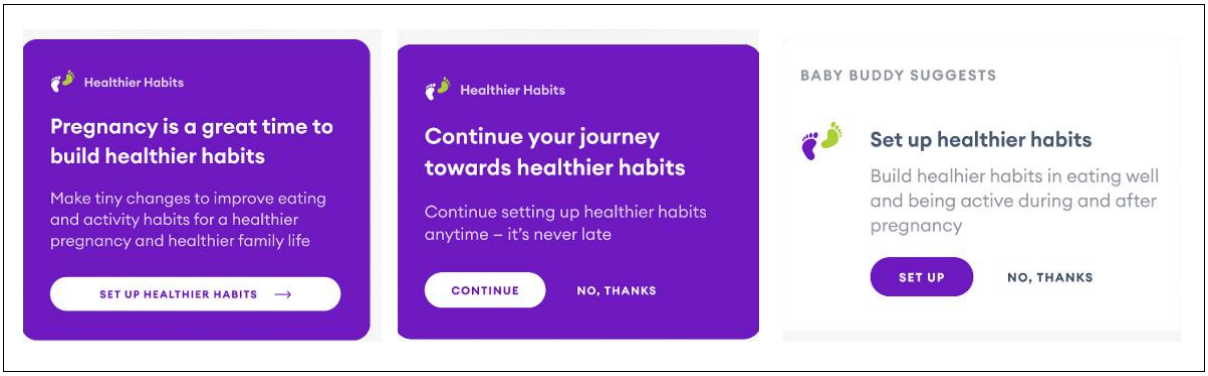
Figure 8-1: Baby Steps to Healthier Habits structural design



8.2 Invitation to onboard message

Only Baby Buddy antenatal users who have downloaded the free app and are registered will be sent a BaSHH invitation message. Users registering as expectant parents will receive this messages in their daily information feed within the first week of registration. It will include a link to the onboarding section. If users start the onboarding process, but do not complete it, they will receive a prompt message to continue the following day. Reminder messages will appear until the invitation is declined (see Figure 8-2).

Figure 8-2: Recruitment messages



8.3 Onboarding

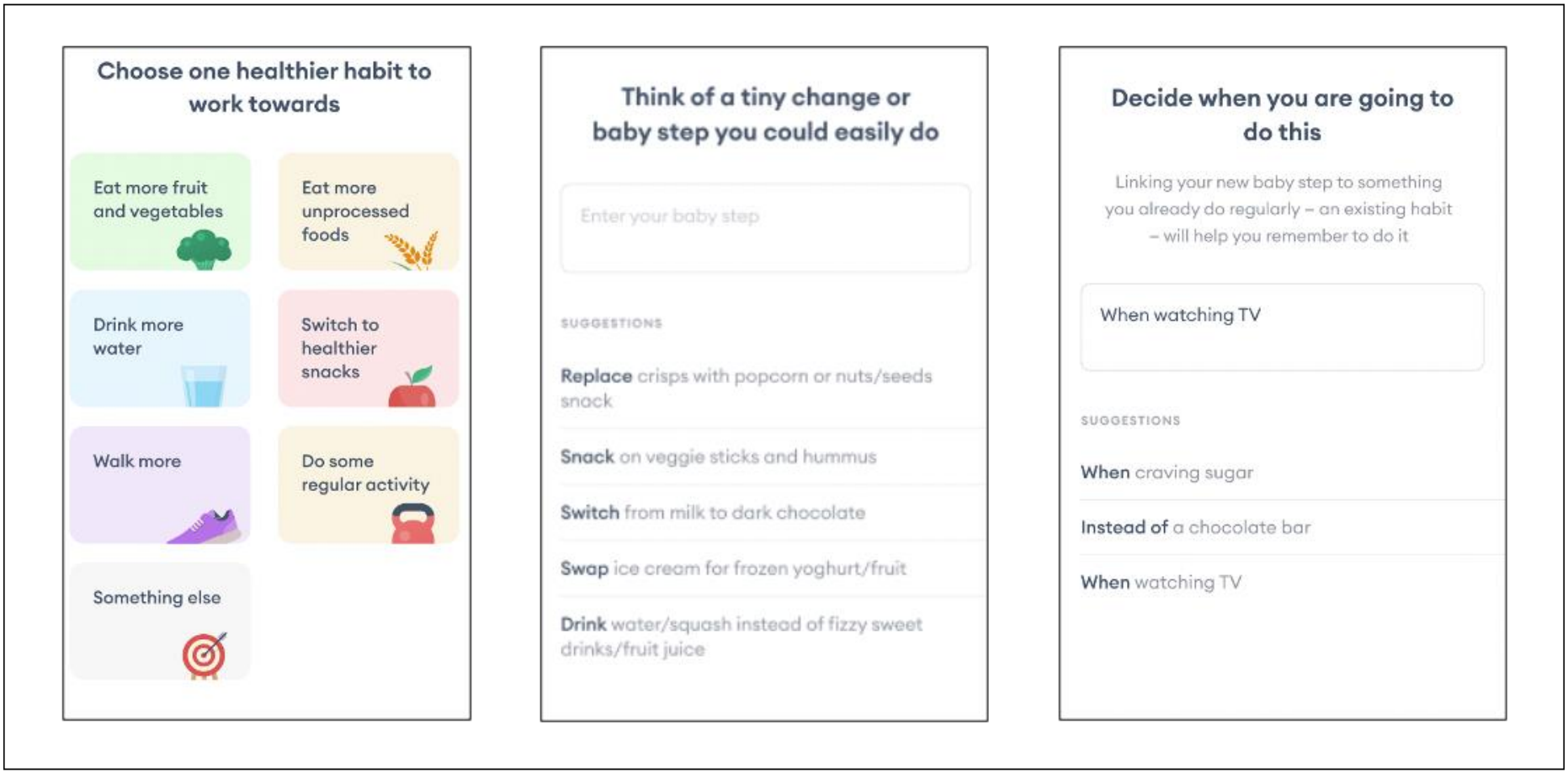
A decision was made with Best Beginnings and the app designers to build a series of onboarding screens that potential users could scroll through at their own pace rather than to follow the original plan of creating a series of short, animated films. This was both a result of Stage 3 participants' views of wanting control over the speed of their onboarding journey, and because it was felt to create a more modern, Instagram-style look for the intervention. This, it was felt, would increase familiarity and ease of engagement. The onboarding process briefly describes the purpose and content of BaSHH as well as the user benefits. Potential users are then guided through the set-up procedure for selecting a healthier habit to work on and creating their first baby step. This procedure was based on Fogg's Tiny Habits method, where individuals are led through a process that helps them to decide what new habits they want to work on, which new habits they are most likely to succeed in and what the tiniest form of this new habit might be (Fogg, 2020). However, Fogg's process was not designed as

a self-directed digital exercise and Study 3 findings suggested that rather than going through the exercises to identify which healthier habit to work on, users would prefer to select from pre-set categories (see 7.3.4.5). The option to create their own healthier habit was retained (a seventh option). These healthier habit options are shown in Figure 8-3. Once a healthier habit has been selected, users will be presented with some example baby steps. Once again they can either choose a pre-set baby step or input their own baby step. Once users have chosen their healthier habit and set up their baby step, they will be asked to decide when they are going to perform this baby step with the recommendation to link it to an existing behaviour, and to select which days each week or number of times per week they will take this baby step (see Figure 8-3). Finally, they will be given an opportunity to set up push notification reminders to complete their baby step.

Consistent with Fogg's Tiny Habits method, the final section of the onboarding reminds new users of the importance of celebrating each time they take a baby steps. It also encourages them and gives them tips for how to prepare for their healthier habit journey.

Once the onboarding process is completed, users will be taken to the BaSHH home screen or dashboard, where they will be able to access several features. These are explained individually in the next section.

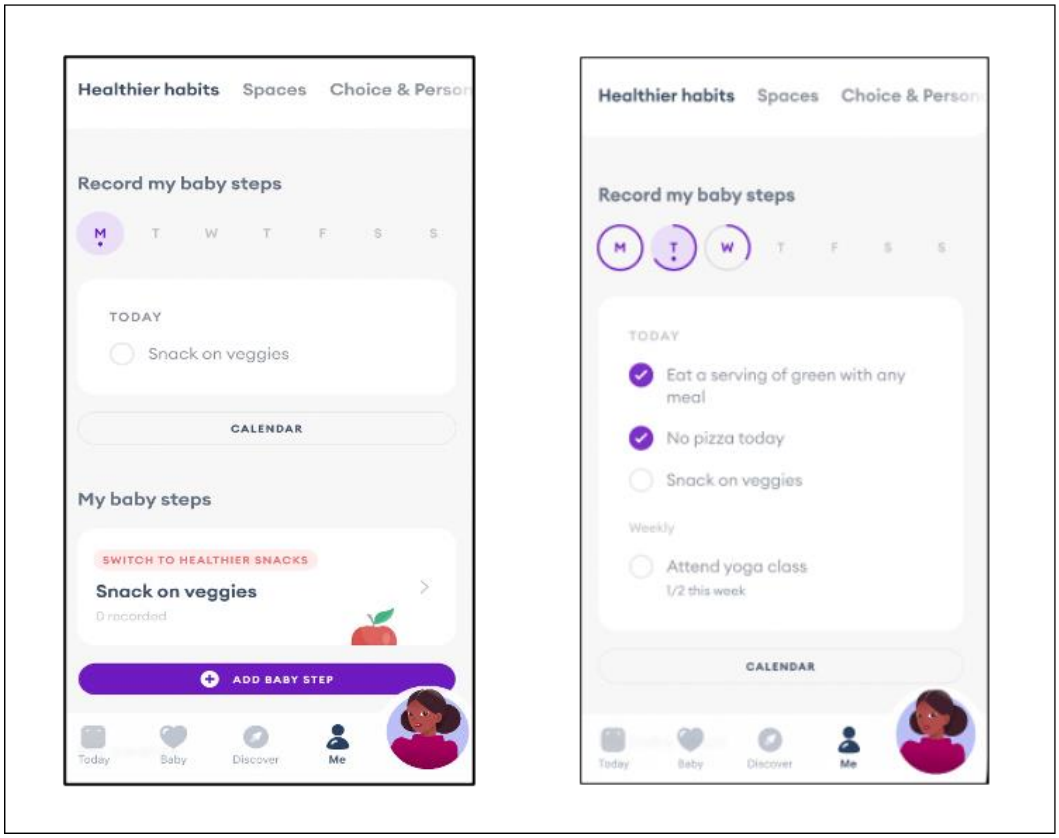
Figure 8-3: Healthier habits and baby steps selection



8.4 Record my baby steps

Users will be able to tap to record that they have completed their baby step on a particular day. The relevant day of the week will be highlighted, and a circular outline will reflect the proportion of baby steps achieved that day (see Figure 8-4). Participants will be encouraged to complete this information daily but it will also be possible to complete this information retrospectively, if needed.

Figure 8-4: My baby steps



8.5 Adding a baby step

This button will take users to the space where they can add a new baby step, in the process described in section 8.3. It is possible to work towards as many goals and include as many baby steps as they want to.

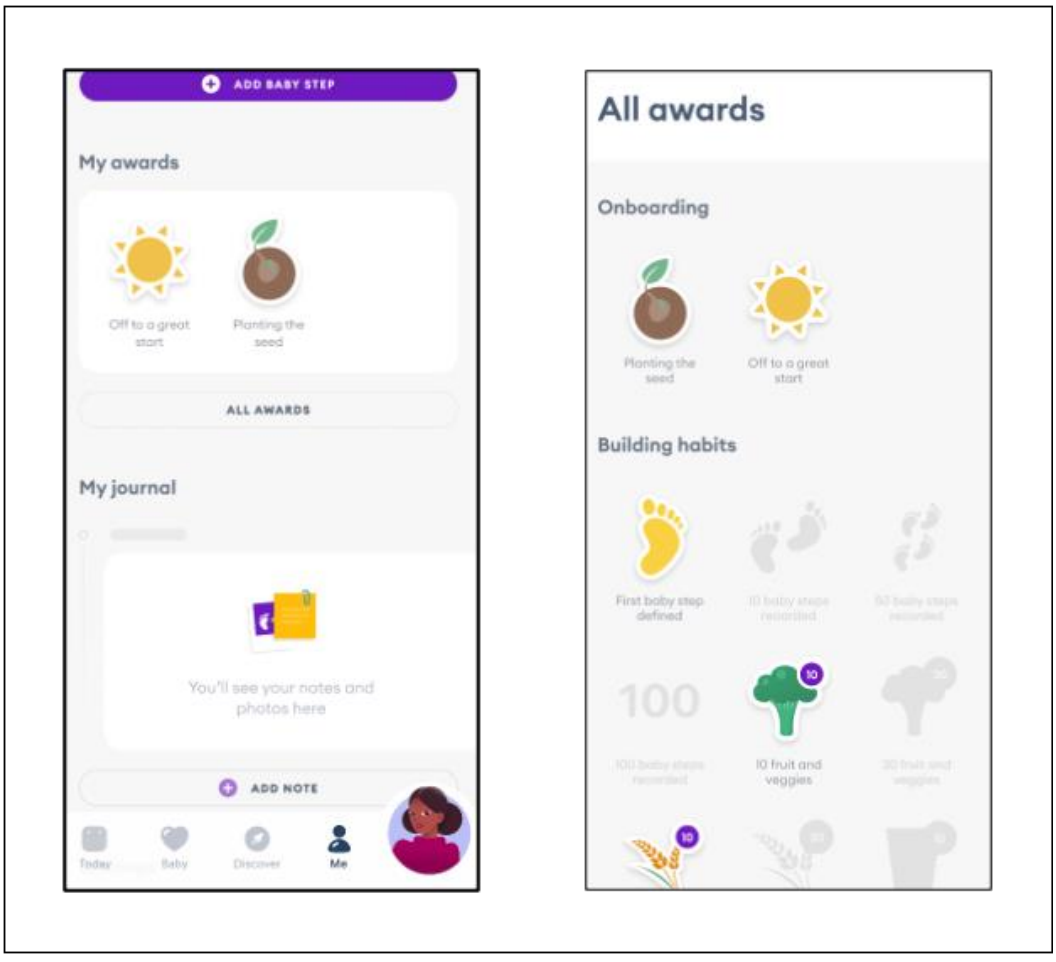
8.6 Calendar

In this section, users will be able to scroll back day by day to see the extent to which they have achieved their intended baby steps. There will also be an opportunity to record baby steps they may have previously missed.

8.7 Awards

This space will show users the virtual awards they have achieved and a link to all awards available (see Figure 8-5). Awards relate to the number of baby steps recorded. Different icons are awarded for each of the healthier habit goals. For example, users working towards the healthier habit of eating more fruit and vegetables are awarded broccoli spears. Awards will also be given for completing various sections of the intervention, such as the onboarding process.

Figure 8-5: Awards



8.8 Journal

The journal is a space where users can record their daily thoughts or add photos or pictures. Users will receive a push notification early on in their BaSHH journey to encourage them to check out this area and consider adding a pledge or promise to themselves.

8.9 Settings

In this area users can change who they choose to share with and opt in or out of notifications. When users choose to share with a partner or buddy, they will still be asked and required to confirm their desire to share their healthier habit goals, baby steps, progress, feedback or journal entries before the information is shared.

8.10 Bite-size messages

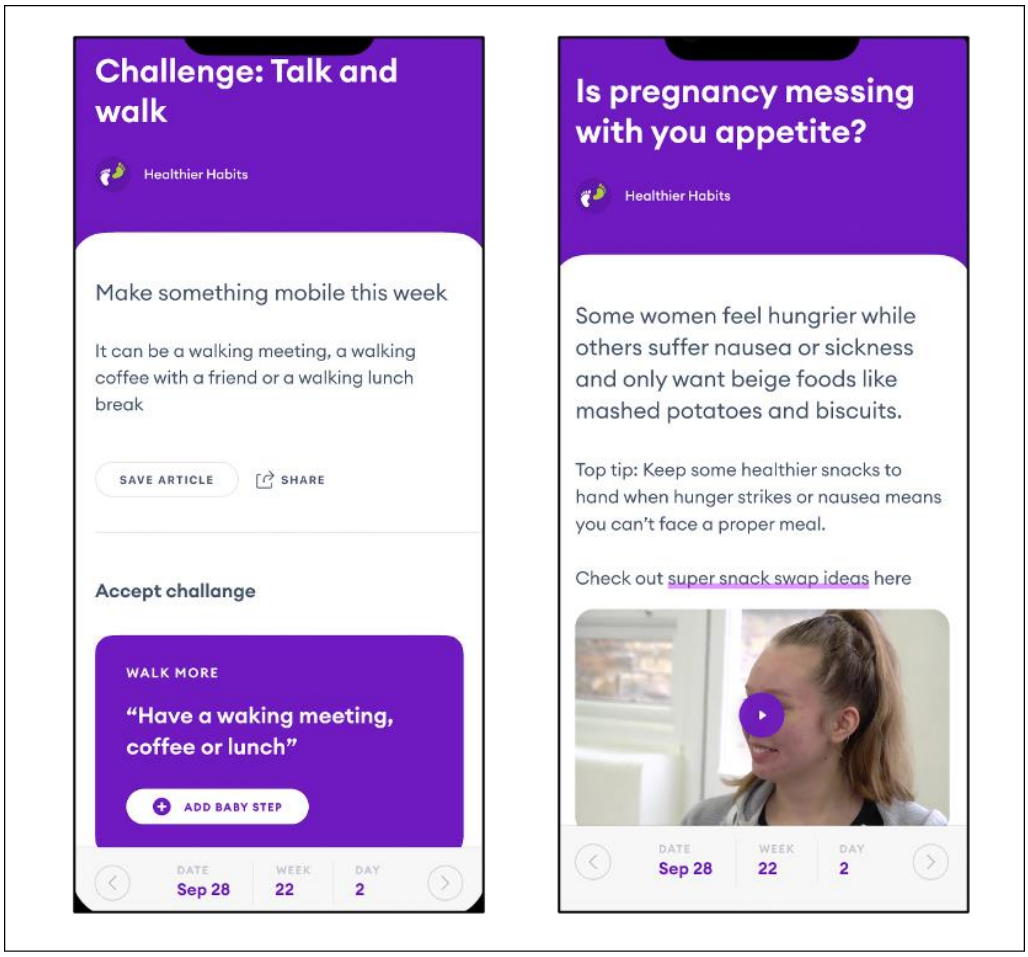
Figure 8-6 illustrates examples of bite-size messages as they will appear in users' daily feed. A total of 32 weeks' worth of gestational-age-appropriate messages have been written (approx. 160, including separate partner messages), starting from 6 weeks gestation and ending at 38 weeks' gestation. These messages were edited by Best Beginnings' writer and reviewed by Best Beginnings' Editorial Board. Users will receive the messages appropriate to their stage of gestation. Each week of messages follows the following format:

- Monday – Weekly Challenge. This will be a simple and low-agency behaviour change suggestion such as 'Soup challenge: Try one of our simple soup recipes this week' and 'Active challenge: Make a date with someone for a walk or some other activity this week'. Users will have the option to add the challenge to their baby steps to receive reminders and record their progress. These challenges will be sent to all users, regardless of their healthier habit goals.
- Tuesday – Top Tip (dietary). These messages will cover a broad range of general dietary issues such as the negative health consequences of ultra-processed foods, hidden free sugar in foods, in-utero development of baby's taste preferences and how to increase vegetable intake. Most messages will include a link to a film, further written content or a recipe idea, all of which will

be available to all Baby Buddy users, regardless of whether they are participating in the intervention.

- Wednesday – Top Tip (physical activity). These messages will include tips on how to increase activity levels and reduce sedentary behaviour. Messages will link to exercise videos within Baby Buddy and on NHS approved sites (Couch to Fitness (Prenatal) and Active Pregnancy Foundation). Sleep and stress reduction tips will also be included.
- Friday – Additional interesting dietary or physical activity fact or top tip. These messages may build on messages earlier in the week or cover a new topic.

Figure 8-6: Examples of bite-size messages



8.11 Reminders

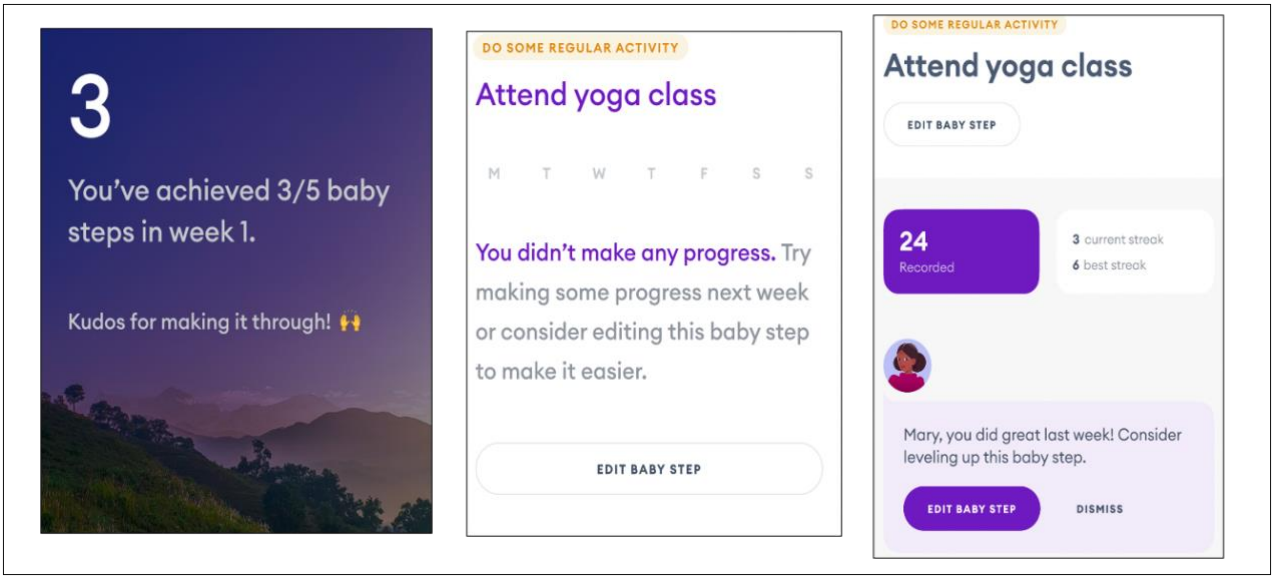
Users will be able to set up reminders to suit their own baby steps schedule. These will appear in the daily feed. All users will receive a reminder on Saturday to check

that they have recorded all their baby steps for the week ahead of weekly feedback on Sunday.

8.12 Feedback

Users will receive feedback on their weekly progress each Sunday (see Figure 8-7: Feedback messages. This will be based on the percentage of baby steps they have completed during the week. Four levels of feedback messages have been designed – over 85% completed; 41%-84% completed; 1%-40% completed and 0% completed. For each level three messages have been written and these will be rotated to minimise repetition. Two additional movement messages have been written alongside movement rules for when a user moves up a level after slipping down a level. All messages were approved by two independent psychotherapists. Examples of the feedback messages can be found in Appendix 14.

Figure 8-7: Feedback messages



8.13 Films

Experts in their fields - Professor Giles Yeo (professor of molecular neuroendocrinology at the University of Cambridge), Dr Chris van Tulleken (an infectious diseases doctor at University College London Hospitals) and Paula Lavandeira-Fernandez (GDM midwife at Surrey Heartlands CCG) kindly volunteered

their time to make series of 10 short films to explain and endorse some of the key intervention messages (see 0). Consistent with Best Beginnings' style, these films are typically around 90 seconds long and informal. Language is intentionally simple and any terminology that might not be familiar to users is explained. Once the intervention is live, peer-to-peer films will be made with users.

8.14 Recipes, snack ideas and weekly meal plans

Between 20 and 30 simple recipes were selected, developed and curated for inclusion in the app, adding to those already in Baby Buddy. Further recipe ideas will be provided via links to external sites. These recipes will include options for vegetarians and vegans and will cover a range of different world cuisines. The app will also include 10-15 healthy snack ideas and 2-3 weekly meal plan ideas.

8.15 Other written content

Baby Buddy already contains some information on diet and physical activity in pregnancy. However, other written content was added to support the bite-size messages. This included healthy snack ideas, tips on how to eat more vegetables, sleep tips and breathing exercises for stress and relaxation.

8.16 Links to external sites

A number of the bite-size messages link to external sites. On the dietary side, these include links to approved sources such as NHS UK, Diabetes UK and The British Heart Foundation. On the physical activity side, links to the Active Pregnancy Foundation site and Couch to Fitness (antenatal) provide access to activity ideas and fitness classes specifically for pregnant women. These sites have been selected based on their information being evidence-based and the links stable.

8.17 Conclusion

The fully detailed intervention design as described above emerged from the user research, input from PPIE and stakeholders and evidence from published literature. Before investing in building the feature, it was agreed with Best Beginnings that one

final stage of user research should test the user interface and user experience. This study is described in the next chapter.

Chapter 9 Study 4: Testing the Baby Steps to Healthier Habits prototype using think aloud interviews

This chapter describes Study 4, the final stage of user research. This study used think aloud interviews amongst current pregnant Baby Buddy users to explore reactions to the user interface and the user experience of a prototype of BaSHH. The research helped me to identify aspects of the design which needed further tailoring before briefing the app builders.

9.1 Introduction

Following Study 3, a final intervention design concept was developed as described in Chapter 8. This was presented to and agreed with Best Beginnings. The features of the intervention were based on the findings from Studies 1-3, using the BCW approach to integrate the most appropriate BCTs into the intervention and FBM and Tiny Habits to design the procedure for guiding users through behaviour change and habit formation (Fogg, 2020; Michie et al., 2011). The development process involved various phases, creating a range of interactive elements and novel features and determining how these could be seamlessly integrated to produce a viable and scalable intervention feature to sit within the Baby Buddy app. The culmination of this process was a BaSHH prototype and the aim of Study 4 was to use this prototype to investigate user response to the BaSHH user interface and user experience.

9.2 Method

9.2.1 Study design

Online ‘think aloud’ interviews were used to investigate the real-world user experience and the user interface. This methodology encourages participants to engage with an intervention, verbalising their thoughts as they do so (Ericsson, 2008). For online video think aloud interviews, participant share their screen, so the moderator can follow the sequence, noting the speed and ease of navigation through the digital intervention prototype. The moderator remains silent throughout this process, unless their help in navigating the prototype is required. Once the participant has navigated through the

prototype, more traditional interviewing techniques are used to explore reactions to the user experience and the user interface.

9.2.2 Participants and recruitment

Participants were all current Baby Buddy users. An in-app notification was sent to pregnant Baby Buddy users asking them if they would like to try out a new feature coming soon to Baby Buddy and to take part in some research being conducted by UCL on Best Beginnings' behalf. The notification was sent May 2022. Those who responded were linked through to a questionnaire where contact details were collected, along with demographic information (age, highest educational qualification, gender), ethnicity, number of children under 5 years of age, and pregnancy status. Participant selection was based on these criteria with the aim of achieving a demographically and ethnically diverse sample. The final sample size was determined by the data saturation method – once no new data and insight were being uncovered in the interviews, the interview process was deemed completed (Saunders et al., 2018).

9.2.3 Stimulus materials and interview procedure

The prototype of the BaSHH feature was emailed to participants at the beginning of the interview so that the participants would see the materials for the first time during the interview. The participant was asked to share their screen so that the moderator (AR or AP) could observe their progress as they navigated through the prototype, paying attention to the ease and speed with which participants completed this exercise. Participants were asked to use the app prototype as they would in real life, voicing their thoughts out loud as they did so. The prototype started with the recruitment message in the Baby Buddy daily feed and took participants through the onboarding process. Once the onboarding process was completed, participants could view the BaSHH dashboard and test out the various elements (see Chapter 8). Full functionality was not available on all the features at the time of his study and where personalisation choices had to be made to proceed (e.g. selecting a healthier habit), these were pre-programmed. All interviews were audio recorded. Consent to audio record the interviews was confirmed at the start of each interview.

9.2.4 Analysis

After each interview, any navigation issues were reported directly back to the app designers via email so these could be fixed ahead of subsequent interviews. AR and AP discussed and collated their findings in word documents. Consistent with the PBA's Table of Changes, potential changes were identified, along with the reason for each change as well as the importance of the change, as described in section 7.2.7. A word document was shared with Best Beginnings and the app designers at two points during research - midway through the fieldwork and after the final interview. Decisions as to which of the proposed changes should be actioned were made jointly with Best Beginnings and their app designers, and based not only on the results of this research, but also considerations such as ease and cost of build and consistency with other aspects of the Baby Buddy app.

9.2.5 Ethics

Approval for this stage of research was granted by University College London Research Ethics Committee (16749/002).

9.3 Results

9.3.1 Characteristics of study participants

The characteristics of participants are summarised in Table 9-1.

A total of 55 Baby Buddy users responded to the interview request and 19 think aloud interviews were conducted. Interviews lasted between 30 and 45 minutes. Most participants were female (n=18; 95%), reflecting Baby Buddy's current user-base. (The recruitment took place less than 6 months after the fathers' pathway had been launched.)

Table 9-1: Characteristics of study participants

Total	n=19 (%)
Gender	
Female	18 (95)
Male	1 (5)
Age (years)	
<20	0 (0)
20-29	4 (21)
30-35	7 (37)
36+	8 (42)
Ethnicity	
White	11 (58)
Black	3 (16)
Asian	4 (21)
Education	
GCSE	1 (5)
A level	2 (11)
Graduate	7 (37)
Post-graduate	9 (47)
Pregnancy/baby status	
First pregnancy/baby	16 (84)
Second+ pregnancy/baby	3 (16)
Pregnant	11 (58)
Baby < 18 months	8 (42)

9.3.2 Summary of changes

Overall participants responded positively to the prototype and identified few problems with either navigating or understanding the contents.

9.3.2.1 Messages, imagery and branding

This research provided important feedback on the onboarding visual imagery. Watching and listening to participants navigate through and respond to screens during the think aloud interviews drew attention to the messages and images that were particularly engaging and motivating.

Saying how it's important for your baby and having the scan picture is really good – that would have made me want to do it – you're doing it for your baby (Female #13)

I like that it says don't over reach – it's like 'We want to make it as easy as possible' (Female #5)

Design features such as the background visuals, emojis and highlighted text appealed to participants and were generally thought to create a contemporary and appealing feel.

I like how it's broken up – it feels a bit like Instagram (Female #4)

Whilst the range of visual images was thought to imply inclusivity, some participants suggested including more images of women with overweight or obesity and women wearing head coverings. Importantly, participants provided feedback on unintentional but potentially negative associations. It was agreed that all visual images would be reviewed to ensure a broad representation of body types and ethnicities and to avoid any unintended stereotyping.

When it's about mental well-being they always use a black lady. Why not have the black lady doing the physical health thing and a picture of a white lady for the mental health? (Female #7)

They are very nice pictures but it would be nice to see some more plus size women (Female #14)

Using purple text on key words was responded to positively in the early interviews so that this was extended to other screens for later interviews. Participants thought it was attractive and worked well to draw attention to key words.

I like the purple words - it draws you to what's important if you're reading through quickly. (Female #11)

Similarly early interviews revealed a positive response to the use of emojis, not only as a means of communicating a specific emotion, but also projecting a light-hearted

and accessible feel for the intervention. Emojis were added to some other screens for later interviews.

> *I really liked the emojis – makes you feel they are on your level (Female #2)*

Finally, responses to the prototype provided insight into how the use of the baby feet logo could strengthen and clarify communication of the concept of taking baby steps towards a healthier habit goal. As a consequence of this, the logo was added to some other screens.

> *To me those little feet say baby steps – like a shorthand (Female #9)*

9.3.2.2 Length of the onboarding process

It became clear from the interviews that the onboarding process needed to be shortened. Participants felt that whilst the information was interesting and important, the current length (of up to 20 minutes) might act as a barrier to completing the onboarding process.

> *It's too long but it's good for getting women thinking about healthier habits…it takes too long to get to actually setting up your first baby step. (Female #6)*

A decision was made to exclude a series of introductory screens that provided 5 steps to eating well. Whilst this information was deemed important, participants felt that it would slow down the onboarding process and might act as a barrier to completing it. Rather this information would be delivered to users once they had completed the onboarding process but prior to the programme of bite-size messages commencing.

Similarly, based on observed interactions with the prototype, it was decided that the 'making the promise' (making a personal commitment) activity should be excluded from the onboarding section and introduced to users at a later stage.

> *I'd want to be able to skip that bit. I might upload a scan photo or something but not now (Female #3)*

9.3.2.3 Choosing your first baby step

Study 3 had identified that many participants wanted pre-set healthier habit suggestions to choose from. In this stage of research participants suggested having pre-set baby steps to give them ideas on what they might choose as a first step towards their healthier habit.

> *I like that you can click on one of the habits. It would be even better if there was a drop-down menu of suggested baby steps, so you didn't have to stop and think of one there and then. (Female #7)*
>
> *Some ideas would be good – like 'here are some places you can start' (Female #1)*
>
> *I don't want to have to type anything in – just click on it (Female #13)*

Pre-set ideas for when to perform the baby step were also suggested. It was agreed that pre-set options should be provided in both instances.

9.3.2.4 Calendar and diary

On the main home dashboard, having both a calendar and a diary appeared to cause confusion.

> *It's confusing having a calendar and a diary….maybe call it a journal or my progress. (Female #10)*
>
> *To me a diary is for appointments. (Female #9)*

Participants found it hard to imagine using the calendar and the purple circles indicating the proportion of the day's baby steps had been achieved were not intuitive. It was agreed that the design of the calendar should be reconsidered to make it more intuitive.

The idea of a space where users could record their own thoughts and photos was appealing. However, rather than diary, participants suggested alternative names including 'My progress', 'My logbook' or 'My journey'. It was agreed that this feature should be renamed.

I might want to add to the diary a life vent that meant everything went to pot that day. (Female #8)

9.3.2.5 Feedback messages

Whilst the concept of feedback messages appeared to work well, participants felt that these should always be positive and motivating, even when little or no progress had been made. Several participants found the use of percentages to be either confusing or off-putting and as such a decision was made to exclude these.

Saying you didn't make any progress this week is too negative. Even if you haven't, I think the feedback should be positive – encouraging you to do better next week (Female #7)

Having the percentage of baby steps you've done makes it feel like a test. (Female #9)

9.3.2.6 Virtual rewards scheme

The collectable badges relating to the different healthier habits had broad appeal. Being able to see the badges that could be collected (in the section labelled 'All Awards') was thought to be motivating. However, several participants noted that the egg icon which was used to track progress towards the 'eat more unprocessed foods' healthier habit would not be relevant to those on a vegan diet. Hence this was changed to an ear of corn.

I really like that you can see all the awards then you know what you are reaching for. You get drawn in like "I want that one". (Female #10)

I really like awards. I used to have stickers in my diary – very sad, very childish, but I needed them to keep me going (Female #9)

9.3.2.7 Navigation issues

Participants in the early interviews identified three navigational problems which were addressed iteratively for the subsequent interviews. These were:

1. Confusion about how to progress through the onboarding screens. A decision was made to include ‘continue’ and ‘back’ buttons on the bottom of each screen.
2. The need to be able to record a baby step directly from a user’s daily feed as well as via their BaSHH dashboard. A decision was made to add this functionality.
3. The positioning of the message “Before sharing you will always have to confirm first”. A decision was made to move this to *before* choosing a Healthier Habits Buddy rather than *after,* thus reassuring users that they will always be in control of what they share *before* signing up to share with a partner or buddy.

9.4 Discussion

The think aloud interviews completed with 19 existing Baby Buddy users provided valuable ‘real world’ feedback to the BaSHH prototype. Potentially problematic issues with navigation and terminology were resolved and changes were made to shorten and simplify the onboarding process, thereby reducing the risk of non-completion and increasing initial engagement. Comments on visual imagery and branding led to the increased usage of emojis and the BaSHH little feet logo. New visual images were also introduced to communicate a greater sense of diversity and inclusivity.

The importance of a simple onboarding process and straight forward feedback has previously been highlighted in a systematic review of 41 quantitative, qualitative and mixed methods studies on the influences on the take-up and engagement with health and well-being apps (Szinay, Jones, Chadborn, Brown, & Naughton, 2020). The authors suggest that providing instructions on how to use the app and advice related to the target behaviour will help with initial engagement. The look and ‘feel’ of an app has also been identified as an important factor in choosing an app (Perski, Blandford, Ubhi, West, & Michie, 2017). Perski et al’s study, investigating how users choose and engage with smoking cessation and alcohol reduction apps, used think aloud interviews (n=20) to identify design features that influence decision making. Consistent with potential users of BaSHH, participants favoured a modern and minimalist appearance. Desired BCTs (goal setting, self-monitoring and feedback, rewards and prompts) and tonal preferences (tailoring of content and a non-judgmental communication style) mirrored those within BaSHH.

This study also highlighted the importance of visual imagery in communicating inclusivity. The need for cultural diversity in health apps, with regards to the content provided and imagery used has been identified previously (Coughlin, Whitehead, Sheats, Mastromonico, & Smith, 2016). However reviews suggest that lack of cultural representation and lack of consideration of cultural concerns and norms remain key barriers to using lifestyle apps or digital health more broadly (Shabir et al., 2022; Whitehead, Talevski, Fatehi, & Beauchamp, 2023). Involving users from marginalised communities in the development of apps and ensuring that minority communities are represented in the app is essential to ensure sustained engagement (Brewer et al., 2019).

9.4.1 Strengths and limitations

A strength of using the think aloud approach to test the prototype was that it replicated the real-life experience of users discovering and learning about an app feature and provided insight into spontaneous reactions. There are drawbacks of this approach, such as a tendency for participants to put themselves in the role of an app designer and comment on details that, as users, they might have ignored. Moreover, there is a risk of social desirability bias leading participants to be more favourable with their responses about the feature in order not to impair the rapport with the moderator. A further limitation of think aloud interviews is the inability of the moderator to interrupt the participant as they progress through the exercise and ask, ‘why do you think that’, thus limiting the depth of understanding and potentially leading the moderator to draw their own conclusions as to the reason why. To mitigate this the moderators conversed more freely with participants towards the end of the interview, revisiting comments that participants had made during the think aloud phase.

A limitation of this research is that the sample included only one male participant as only one male Baby Buddy user responded to the in-app recruitment notification. There was neither the time nor the budget to employ additional methods to recruit expectant fathers. Moreover, whilst it could have been possible to include expectant fathers who were not current Baby Buddy users, this would have necessitated an explanation about the Baby Buddy app at the start of the think aloud sessions which would have undermined the attempt to replicate the real-world user experience.

This research is not generalisable. Firstly, all participants were Baby Buddy users. Whilst this meant they were already familiar with pregnancy apps and understood the specific context in which the BaSHH feature will sit, the findings only provide insight into how current Baby Buddy users may react to the BaSHH prototype. Secondly, whilst the findings might provide useful insight for other app-based intervention designers, they are specific to the BaSHH feature.

Finally, this research cannot be seen as a predictor of real-life engagement and full use of BaSHH. Whilst all efforts were undertaken to emulate the use of the full app feature, certain constraints were in place which meant not all functionalities could be tested. It also was not possible to test what aspects of the app could contribute towards long-term user engagement, which will be essential to the effectiveness of the intervention.

9.4.2 Conclusions

User testing of the BaSHH prototype confirmed the appeal of the overall intervention design and its branding. Valuable feedback enabled changes to be made to the design to overcome potential barriers to uptake and create a simpler, more intuitive user interface. Data from this study helped to determine the final design of BaSHH and once this was agreed with Best Beginnings, the app builders were briefed to build the feature within Baby Buddy.

Chapter 10 Concluding discussion

10.1 Principal findings

Data on dietary and physical activity behaviours in pregnancy in the UK, especially at a population level, are sparse. However, these data, in conjunction with general population data, indicate that current health behaviours are sub-optimal (Charnley et al., 2021; Khaled et al., 2019; PHE, 2019). Eating a nutritious diet and being physically active is important during pregnancy given the substantial health gains to mother and baby that can be achieved (da Silva et al., 2017; Gilmore et al., 2015; Zaragoza-Martí et al., 2022). In the wake of technological advances and greater population penetration of mobile phones, an app-based intervention offers a scalable and cost-effective way to deliver a health behaviour change intervention to improve dietary and physical activity behaviours during pregnancy.

This thesis aimed to develop a digital intervention to encourage healthy eating, and physical activity in pregnancy for the existing and widely used pregnancy and parenting Baby Buddy app. Consistent with guidance for the development of complex health interventions from the MRC, the intervention development process was collaborative and underpinned by theory (O'Cathain et al., 2019). The PBA to digital health intervention development was applied to ensure that the needs and opinions of target users were understood and accommodated at all stages of the development process (Yardley, Ainsworth, Arden-Close, & Muller, 2015). Additionally, co-creation of the intervention functionality and content with Best Beginnings combined the strengths of academic rigour with real world experience of designing effective digital health products.

To achieve this aim, the overarching intervention structure was theory-based, drawing on the COM-B model to determine the most appropriate BCTs to include in the intervention and to understand the facilitators and barriers to engaging in the intervention as a couple (Michie et al., 2013). A summary of the final BCTs used in BaSHH can be found in Appendix 13. To supplement this approach elements from FBM and Fogg's Tiny Habits approach were incorporated to guide the design and process of user engagement with identified key BCTs (Fogg, 2009, 2020). User

feedback at each stage of the intervention development process (n=83 total participants) shaped the content, functionality, style and tone of the intervention. In addition, a PPIE group contributed to the development of the intervention and the design of the research studies. A multidisciplinary team (n=14) including dieticians, physical activity experts, HCPs and psychotherapists provided ad hoc input into the intervention content.

10.2 Summary of thesis findings

The topics of this thesis were explored using four main research aims as laid out in Chapter 2. These aims were addressed across four studies. Study 1, a systematic review and meta-analysis, informed the rudimentary concept design by identifying potentially effective BCTs. Study 2, the initial stage of user research, tested the rudimentary concept and generated ideas for the intervention design. Study 3, a second stage of user research, explored responses to the detailed intervention design. Finally, Study 4 used a prototype of the intervention feature to test the user interface and user experience.

Aim 1: To learn from existing digital antenatal interventions focusing on healthy eating, physical activity and GWG by examining their overall effectiveness and identifying key drivers of their effectiveness.

In Study 1, RCTs of exclusively digital interventions (n=11) to encourage healthy eating, physical activity and optimum weight gain in pregnancy were systematically reviewed and meta-analysed. In addition to reporting on their effectiveness this study investigated levels of engagement with the interventions and their use of BCTs. The meta-analyses showed lower mean GWG for exclusively digital interventions compared to control groups for ITT studies and PP studies, although these differences were not significant. (ITT data (n=3) mean difference in total GWG -0.28kgs (95% CI: -1.43, 0.87) (I^2 = 0%, P = 0.38), PP data (n=4) -0.65kgs (95% CI: -1.98, 0.67) (I^2 = 53%, P = 0.10)). Overall the findings suggested that exclusively digital interventions may be less effective than in-person interventions, but they can be effective, particularly when they achieve high levels of user engagement with key BCTs. The findings indicated that important BCTs were goal setting (behaviour), self-monitoring

(behaviour), problem solving, review behaviour goal and feedback. Levels of engagement with these interventions varied considerably, but those with highest levels used techniques to encourage interactivity such as regular in-app messaging or text messaging to remind users to track their behaviour or to provide encouragement and feedback on a user's progress. Whilst social support appeared in several of the interventions, none actively included women's partners in this role. This indicated the value of exploring the potential of an intervention that would be flexible enough to harness the influence and support of a partner during pregnancy.

Aim 2: To understand expectant parents' views on a feature within a pregnancy app to encourage and support healthy eating, physical activity and healthy GWG.

Study 2 explored the concept of an app-based healthy eating, physical activity and GWG intervention targeting expectant couples (n=30). Including partners in the intervention received a positive response from male and female participants, although the latter considered it important that partner involvement was optional. The study also explored reactions to the rudimentary intervention concept and used thematic analysis to identify 11 themes that helped to guide the design and content of the intervention. It provided important insight into not only the features of the intervention that users would like, but also the appropriate tone of voice for the intervention. The study also highlighted the need to design content to promote sustained engagement over time, a key challenge in digital health interventions. From this study, a detailed intervention design was developed.

Aim 3: To identify barriers to using such a feature and determine how these can be overcome to ensure good uptake and sustained engagement.

Study 2 also explored the barriers and motivations to engaging in the intervention as a couple. The findings were mapped to COM-B and TDF which helped to bring focus to the type of messages that were important to convey in the promotion and onboarding in order to encourage enrolment in the intervention. These findings were also used to shape some of the bite-size intervention messages for both women and their partners.

Aim 4: To design a theory-based digital behaviour change intervention to encourage and support healthy eating, physical activity and healthy weight gain in pregnancy.

Studies 3 and 4 focussed on developing BaSHH, iteratively evaluating and refining its design and content, through to its final form. Study 3 investigated response to the fully worked up BaSHH intervention concept, using qualitative interviews with individuals and couples (n=34). This study was conducted over a 6-month period during which changes were made to the intervention design and content in line with participant feedback and input from the PPIE group, Best Beginnings and a wider group of behavioural and health experts. A key finding from this stage of the research was that weight messaging could act as a barrier to participating in an antenatal healthy eating and physical activity intervention and as such the decision to exclude weight messaging and focus solely on messages around positive health behaviours was made. Study 4 tested the user interface and user experience using an intervention prototype. Think aloud interviews with 19 current Baby Buddy users helped to identify potential usage issues and provided guidance for optimising the final BaSHH app feature. Following participant feedback, the onboarding process was significantly shortened and changes were made to some of the visual images and terminology used to describe features.

10.3 Strengths and limitations

The strengths and limitations of each study within this thesis have been discussed in the relevant chapters. There are however some strengths and limitations that apply across the thesis as a whole.

The development of this intervention was a collaborative process, combining the rigour of an academic approach with Best Beginnings' real-world experience of developing a perinatal app and the team's deep understanding of the target user. Consistent with MRC guidelines for developing complex interventions to improve health and healthcare, a dynamic iterative process began by reviewing published research evidence and drawing on existing theories, before undertaking several stages of user research (O'Cathain et al., 2019). A diverse PPIE group ensured the involvement of

stakeholders throughout the process. The findings of this thesis have advanced understanding of the potential opportunities to improve health behaviours during a crucial developmental period for both mother and baby.

Whilst this intervention has been designed specifically for the Baby Buddy app, the transparent reporting of the intervention development process may be beneficial to other researchers developing behaviour change interventions. Each stage of the intervention development process has been reported in detail and published in open access journals to afford wide sharing and thereby accelerate research in this area. Three publications have arisen directly from this thesis (Rhodes et al., 2023; Rhodes et al., 2021; Rhodes et al., 2020). An additional COVID-19 pandemic-related publication not reported in this thesis helped further understanding of expectant and new parents' needs, attitudes and behaviours during the pandemic (Rhodes et al., 2020). To date, these publications have achieved 87 citations (September 2023).

10.3.1 Representativeness of the samples

The PBA stresses the importance of accommodating the views and needs of the intervention's target users. A particular strength of this study was the socioeconomic and ethnic diversity of the participants, which aimed to maximise the systematic incorporation of diverse experiences, needs and views. Whilst Baby Buddy is freely available to all in the UK, Best Beginnings is committed to designing interventions that address health inequalities. Hence it was critical to this study that the research samples comprised those from more socially and economically deprived groups whose risk of poor dietary and activity behaviours and adverse pregnancy outcomes is greatest (Haggarty et al., 2009; Thomson et al., 2021). Convenience samples in this sphere of academic research are often biased towards white, heterosexual, graduate-educated participants, whose propensity to respond to invitations to take part in research is higher than those from minority groups and those with lower educational attainment. Across the three research samples in this thesis (n=83), 69% of participants had no post-school education, including 27% with no education beyond 16 years old. Moreover 62% of participants were non-white. However sample sizes meant that there were limitations to the range of ethnic diversity, so the nuanced views and needs of some minority ethnic groups could not be explored. In addition, the user

research samples did not include same-sex couples, although a same-sex couple contributed through the PPIE group.

A limitation of the samples at each stage of user research was that they were self-selecting. Participants were informed of the topics under discussion which meant those who were not interested in talking about diet and physical activity in pregnancy were excluded. This may have had the effect of making response to the concept artificially positive. Nevertheless, an element of interest is required to generate constructive feedback in concept development research. Related to this limitation is social desirability bias - that is the desire of participants to say what they believe the moderator wants to hear. In commercial qualitative research the moderator typically has the advantage of being able to state their independence from the brand or service they are researching. However, in this study the vested interest of the moderators in the development of BaSHH could not be denied. Conscious of this, the moderators made efforts to create an environment in which participants felt able to criticise and challenge the ideas presented to them.

10.3.2 Data collection tools

All stages of user research and PPIE interviews were conducted remotely, using online conference platforms (i.e. Zoom and Microsoft Teams) and telephone interviews. This was not by choice. Restrictions introduced by the COVID 19 pandemic meant face-to-face research was not permitted for Studies 2 and 3. An online methodology was chosen for Study 4 for reasons of cost and speed. An up-side of online focus groups and interviews was they proved to be a more cost-effective and time-efficient way of reaching a geographically diverse audience and as such, sample sizes could be increased.

In Study 2 a combination of individual telephone interviews and online focus groups was used. Research suggests telephone interviews elicit a similar quality of data to face-to-face interviews (Rahman, 2015). Moreover the anonymity they afford can encourage participants to disclose less socially desirable attitudes and behaviour (Block & Erskine, 2012). However the differences between online and face-to-face focus groups are more substantial, as the dialogical conversation typical with a face-

to-face focus group is hard to achieve and more typically the sessions become a series of individual ‘in turn’ responses (Bolin, Kalmus, & Figueiras, 2023). A consequence of this is the need to reduce the number of participants. In Study 2 the maximum number of participants per focus group was five, whereas had the groups been face-to-face there would have been eight participants per group. Moreover in online focus groups the moderator is forced to adopt a chair-person role in inviting each participant to speak and ensuring a fair distribution of air time. This, in turn, limits participants responding to each other’s comments. Finally conducting focus groups online restricts the ability to encourage creativity as interactive discussion is challenging and the opportunity to use projective techniques is limited. The extent to which this affected the intervention design development is unknowable.

Although Study 3 (comprising individual and couple interviews) used an online rather than face-to-face methodology by necessity rather than choice, here the downsides were less evident, not least because the COVID-19 pandemic had normalised this form of communication. Moreover, at this stage of the intervention concept development participants were being asked to respond to rather than generate ideas for the intervention and as such the creative input sought in Study 2 was unrequired.

10.3.3 Qualitative methods

Qualitative methods were clearly appropriate for this type of concept development research, where the aim was to explore participants’ needs and views, encouraging their feedback without the constraints of pre-set questions. Qualitative methods allow a systematic and rigorous exploration of attitudes, behaviours and experiences that enables an inductive approach to research, and in this instance, the bottom-up creation of an intervention tailored to the needs and desires of the target audience. The ability to stray from a pre-set questions means that discussion can be tailored to individual participants, allowing unforeseen ideas and issues to emerge. Moreover, participants can describe their feelings, beliefs and experiences using their own words which can add a further level of insight and important guidance for the language used in an intervention . Qualitative sample sizes tend to be smaller than quantitative, and the research is, by nature, anecdotal, which can lead to the criticism that it lacks generalisability and cannot contribute to the evidence base. However, it is its

anecdotal nature that enables qualitative research to explore complex and multi-layered beliefs, attitudes and behaviours that might not be exposed by more scientific approaches to research (Green & Britten, 1998).

An important limitation of all qualitative research is the influence of the researcher in both moderating the sessions and interpreting the findings. Reflexivity – understanding your role within the research and how your assumptions, views and experiences can influence the research - is an important consideration for all researchers. In this instance the researchers needed to pay particular attention to the potential impact of the differences between themselves and participants in terms of educational attainment and ethnicity. Candid discussions within the research team and a culture of challenging each other's ideas helped to ensure that reflexivity remained a critical element of the interpretation and analysis of participants' dialogue.

10.4 Reflections

10.4.1 Use of theory in intervention development

Consistent with MRC guidelines for developing complex interventions to improve health and healthcare, the development of BaSHH was rooted in theory. However choosing the right theory for intervention development was not a straightforward process. My systematic review and meta-analysis of digital interventions to promote healthy diet, physical activity and weight management in pregnancy (Study 1) revealed the use of six different theories across the 11 studies, with seven studies reporting the use of Social Cognitive Theory. However, the way in which Social Cognitive Theory and other theories were used to inform intervention development was rarely reported in detail, providing little insight into the relevance of these theories to the intervention designs and how therefore the use of a particular theory might be impacting intervention effectiveness. Consequently, rather than aligning my intervention development to one particular theory, I chose to use COM-B and TDF as these models synthesise the key theoretical constructs from 33 different behaviour and behaviour change theories. COM-B and TDF were useful in that they provided a comprehensive framework for rigorous analysis of identifying behaviour change motivations and barriers and determining potentially effective BCTs. However, one limitation of the

BCT taxonomy is that it provides no guidance for translating the 93 theoretical BCTs into user-friendly intervention features. A BCT will only be effective if it is designed in a way that appeals to users, so they engage with it. For this reason, further down the line of intervention development, I also drew on FBM and specifically Fogg's Tiny Habits to design the key BCTs relating to goal setting and habit formation. This model, too, had its limitations. Here the challenge was adhering to the prescribed Tiny Habits approach whilst being responsive to the views of potential users as expressed in Studies 3 and 4. Where the two diverged I chose to listen to participants' views and deviate from the theory. For instance, rather than taking users through the steps to identify their own healthier habit goals and first baby steps, users will have the option to select pre-set ideas, as participants requested. Whether the use of theory leads to greater intervention effectiveness and how theory is applied to the intervention development process remain controversial points (Moore & Evans, 2017; Prestwich et al., 2014). I conclude from this PhD thesis that whilst theory is useful in early stages of intervention development, particularly in terms of ensuring a methodical and comprehensive approach to formulating and structuring ideas, there are times during the process where rigid adherence to theory needs to be challenged and should not necessarily take precedence over user feedback.

10.4.2 Focussing on health behaviours, not weight

This thesis set out with the aim of developing a digital intervention to encourage healthy eating and physical activity in pregnancy in order to prevent excessive GWG. However, a significant impact of adopting the PBA to developing the intervention was the decision to exclude all references to GWG and rather to focus solely on healthy eating and physical activity. Whilst reducing rates of excessive GWG will remain one of the aims of BaSHH, this will be covert and from the user's perspective the goals will be dietary and activity related only. This approach represents a significant divergence from digital (and in-person) interventions in this field to date (Redman et al., 2017; Sandborg et al., 2021; Thomas et al., 2022).

The decision resulted from participants and several PPIE members reporting that weight messages were demotivating and might be a barrier to engaging with the

intervention. This sentiment was voiced in particular by those with lived experience of overweight and obesity - that is those who might benefit most from the intervention.

In support of this approach, there is mounting evidence that self-perception of overweight and the experience of weight stigma (shaming individuals because of their weight) are major barriers to engaging in healthy eating and are associated with increasing weight gain over time (Duarte et al., 2017; Pearl, Puhl, Lessard, Himmelstein, & Foster, 2021; Tomiyama et al., 2018). Robinson, Haynes, Sutin and Daly (2020) propose a model explaining the association between self-perception of overweight with weight gain and poor health outcomes, suggesting fears of social rejection and internalisation of weight stigma lead to psychological distress, the consequence of which is a reduction in health protective behaviours, leading to weight gain and ill health (Robinson, Haynes, Sutin, & Daly, 2020). The authors note that interventions that draw attention to body weight without addressing these mediating factors may counter-productively, promote rather than prevent overweight or obesity. In contrast, weight-neutral approaches to health interventions, such as the Health at Every Size® approach which focusses on health promoting behaviours rather than weight, been shown to have positive effects on dietary and physical activity behaviours (Bacon & Aphramor, 2011; Ulian et al., 2018).

Weight stigmatisation in pregnancy appears to be a common experience. A study of 501 pregnant and postpartum women in the US found that nearly two thirds of participants had experienced weight stigma in pregnancy (Incollingo Rodriguez, Smieszek, Nippert, & Tomiyama, 2020). In the UK, a review of newspaper media portrayals (n=442) of maternal obesity between 2010 and 2021 found consistent negative framing with women being blamed for their weight status, the increased risks it posed to their own health and the health of their child, as well as its negative impact on the NHS (Heslehurst, Evans, Incollingo Rodriguez, Nagpal, & Visram, 2022). The authors' called for an approach that promotes maternal well-being rather than stigmatising maternal obesity; this is analogous to the BaSHH approach of focussing on the benefits of healthy dietary and physical activity behaviours rather than the risks of excessive GWG.

Further support for an intervention that tackles GWG and maternal obesity covertly came from Surrey Heartlands stakeholders and midwife steering group. With their experience of women's sensitivity around weight issues, they felt focussing on healthy eating and physical activity without weight messaging would make BaSHH more acceptable to pregnant women and as such ease their task of introducing, discussing and promoting the intervention. A final voice in favour of a weight-messaging-free approach came from an eating disorders specialist who reviewed the onboarding script and the bite-size weekly messages and was highly supportive of avoiding all references to weight gain and calories.

The decision to exclude weight messaging in this intervention does not undermine the role of weight advice and monitoring in antenatal care. Studies have shown that pregnant women can want to be informed about the risks associated with excessive GWG and to receive advice on weight gain, provided midwives approach the subject with sensitivity and avoid weight stigma (Brownfoot, Davey, & Kornman, 2016; Christenson, Johansson, Reynisdottir, Torgerson, & Hemmingsson, 2019; Knight-Agarwal et al., 2016). Moreover, women in the UK are generally not averse to the introduction of routine weighing during antenatal care and can feel it would be helpful in maintaining healthy weight gain (Allen-Walker, Hunter, Holmes, & McKinley, 2020; Allen-Walker et al., 2017; Daley et al., 2015). However, the evidence for the acceptability and effectiveness of self-weighing (as weight monitoring with BaSHH would be) is less clear. A small scale study (n=25) asked women to weigh themselves once a week for 8 weeks, and to audio record their weight along with their thoughts and feelings (Ferrey et al., 2021). The authors reported that participants had complex emotions around self-weighing but generally thought it to be useful. However this conclusion was based on feedback from less than half the sample (n=10) who had submitted at least one audio recording (8/10 had found it useful). The authors do not know why the remaining participants had consented to participate knowing the study required them to self-weigh, but did not complete the task, although they hypothesised that at least some of the participants might have been uncomfortable with self-weighing. This study also identified participants' anxiety about the potential causes and effects of their weight gains and losses, particularly since self-weighing meant they were receiving no support from HCPs who could have provided information and advice to allay concerns. As such Ferrey et al. concluded that routine weighing might

be better conducted as part of antenatal care. A similar conclusion was reached by Daley et al (2015) in their feasibility and acceptability trial (n=76) of an intervention in which participants were provided with tailored weight gain charts, weighed regularly by midwives at antenatal appointments and asked to self-weigh weekly (Daley et al., 2015). Whilst weight monitoring as part of antenatal care was deemed to be feasible and acceptable, only 58% of participants self-weighed and only 25% recorded weights on their chart, undermining the self-monitoring aspect of the intervention.

It is unclear the extent to which weight messaging and monitoring has contributed to the effectiveness of multi-faceted interventions. Usage frequency of weight monitoring features is rarely reported, but in one large RCT (n=1689) although 70% of participants used the feature once, continued usage over an average 28 week period was very low (median usage 3 times, 25% and 75% percentiles: 0,9) (Graham, Uesugi, Niederdeppe, Gay, & Olson, 2014). Moreover, intervention trials in the UK have reported no effect of routine antenatal weighing or providing women with GWG guidelines (Daley et al., 2019; Sanders et al., 2020). Accordingly, sidestepping weight and focussing rather on the more widely motivating messages of eating nutritious foods and keeping active to promote maternal and foetal health, might be a more effective way of reaching those at greatest risk of excessive GWG.

Avoiding weight messaging and weight monitoring within BaSHH may also be a more sensible approach given that it will sit within the Baby Buddy app and as such will be freely available to all expectant couples in the UK. Although an advisory notice will be included at the start on the onboarding, it will not be possible to screen out those with lived experience of eating disorders or disordered eating. It is estimated that around 7.5% of pregnant women in the UK have lived experience of an eating disorder (Easter et al., 2013) and the prevalence of eating disorders in young people appears to have risen significantly since COVID-19 (Trafford et al., 2023). Although research into perinatal eating disorders is sparse, a systematic review of eating disorders in pregnant and breastfeeding women (n=16) reported associations have been identified between eating disorders and adverse maternal and foetal outcomes (Martínez-Olcina et al., 2020). Another systematic review (n=13) reported an improvement in dysfunctional eating behaviours during pregnancy, with the nutrient intake of those with eating disorders being no different from that of other pregnant women (Dörsam

et al., 2019). However this review also identified some worrying consumption patterns in pregnant women with eating disorders such as high intake of caffeine, in particular from coffee and artificially sweetened drinks. Pregnancy can be a particularly challenging time for individuals who have or have had eating disorders or disordered eating. Concerns about weight gain and body image can be heightened, and as such it is important that BaSHH does not unintentionally trigger disordered eating thoughts and behaviours in any way (Ward, 2008).

A further argument in favour of trialling an intervention that focuses on quality of diet and physical activity rather than weight gain comes from the wealth of new studies showing the importance of quality of diet to overall health and well-being. In particular there is evidence for a consistent association between higher consumption of ultra-processed foods and poorer health outcomes, including obesity. (Atzeni et al., 2022; Dicken & Batterham, 2022; Lane et al., 2020; Pagliai et al., 2021). A notable RCT in which participants followed a two week diet of ultra-processed foods followed by a two week unprocessed diet or vice-versa (where diets were matched in calories, energy density, macronutrients, sugar, sodium, and fibre) reported participants gaining 0.9kgs (SD 0.3kgs; p=0.009) during the ultra-processed diet and losing 0.9kgs (SD 0.3kgs; p=0.007) during the unprocessed diet (Hall et al., 2019). In pregnancy adherence to a Mediterranean diet has been shown to be associated with a reduced risk of GDM and other adverse pregnancy outcomes (Zaragoza-Martí et al., 2022). Conversely meta-analyses have shown that there is mixed evidence of the effect of interventions to prevent excessive GWG on maternal and foetal clinical outcomes (Fair & Soltani, 2021; Teede et al., 2021). Adopting a radically different approach is therefore worth investigating.

10.4.3 Involving partners in antenatal care and interventions

Another point of difference of BaSHH from previous interventions to support healthy eating, physical activity and weight management in pregnancy is the active inclusion of partners, or a healthier habits buddy for those who do not have a partner or would rather their partner not be involved. Over the past two decades fathers' involvement in childcare has increased and the benefits of this to children's emotional, psychological and cognitive well-being as well as to family relationships are well-

documented (Chung, 2021). Given the importance of the antenatal environment to child development, fathering should start in pregnancy (Bakermans-Kranenburg, Lotz, Alyousefi-van Dijk, & van IJzendoorn, 2019). However, fathers/partners continue to report feeling marginalised and unsure of their role during pregnancy (Darwin et al., 2017; van Vulpen et al., 2021). Experiences during the COVID-19 pandemic of partners being excluded from not only antenatal appointments but even the early stages of their partner's labour and recovery period, reinforced the notion of fathers being an accessory rather than a partner in the pregnancy and birth of their child (Andrews, Ayers, & Williams, 2022). Study 2a identified the perceived benefits of a couples' intervention to extend beyond the positive effects on health as a result of behaviour changes. Participants thought it would not only help increase partners' sense of involvement in the pregnancy and preparations for parenthood, but also it might strengthen their own relationship during pregnancy. The effects of the intervention on partners will be explored as part of the evaluation of BaSHH (see Appendix 15).

10.4.4 Sustaining engagement in digital interventions

Study 1 demonstrated the importance of engagement levels to the success of interventions targeting dietary and physical activity behaviours and weight gain in pregnancy. Sustained user engagement will be crucial to the effectiveness of BaSHH. Disengagement with health apps and health behaviour interventions is typically high, especially in longer-term interventions (Gold et al., 2021; Meyerowitz-Katz et al., 2020; Schroé, Crombez, Bourdeaudhuij, & Dyck, 2022). Reasons for disengagement include boredom, loss of novelty, lack of time, high data entry burden, loss of motivation and lack of personalised feedback (Krebs & Duncan, 2015; Mustafa et al., 2022). Study 2b, highlighted the importance of regular and/or varied intervention content to capture and hold users' interest. As such ensuring BaSHH delivers sufficient variety to keep users engaged over conception to birth intervention period, whilst at the same time avoiding being too demanding on their time, was a high priority. To this end, measures were taken to minimise the user-burden of the goal setting and self-monitoring features, prioritising simplicity and ease of usage over rigidly adhering to the theory-based prescribed procedure, for example selecting target behaviours from a simple drop-down menu. A total of 128 bite-size messages were created to add novelty and

interest, along with supporting film and written content, weekly challenges and links to recipe ideas and exercise classes. Feedback messages were tailored to different levels of achievement, with several different messages at each level to minimise repetition.

Another route to reducing the likelihood of disengagement is by creating a sense of accountability amongst users. Participants in Study 2a thought that their likelihood of successful behaviour change would improve if their partners were involved and they felt accountable to another individual. Midwives also identified an opportunity to encourage users to stick with BaSHH by asking about their progress during antenatal appointments. For women at risk of GDM, midwives also suggested extending the sharing facility to create small groups monitored by a midwife, where women could support and encourage each other by sharing tips and stories. Given that in-person interventions tend to be more effective than exclusively digital interventions in this field, the inclusion of an in-person element to BaSHH may be advantageous. Two recent trials have explored supplementing an in-person intervention to improve dietary and physical activity behaviours in pregnancy with an app. The PEARS study (n=565) compared an in-person lifestyle intervention supported by an app with standard care and reported a positive effect of the intervention on dietary and physical activity behaviours (Ainscough et al., 2020). However, in the intervention group, app usage had no effect on physical activity and only minor positive effects on dietary behaviours. Similarly, the SNAPP trial (n=162), compared an in-person intervention to encourage dietary and physical activity change in pregnant women in Australia with and without app support found that the app provided no additional benefit (Dodd et al., 2018). However, the app was used by less than a third of intervention participants. Whilst these findings are not encouraging, it is important to note that the apps in both these trials were additional features of in-person interventions rather than self-contained interventions. Moreover, they were less complex than BaSHH and did not include a behaviour tracking feature, personalised feedback or regular messaging. In their trial of a web-based antenatal nutrition intervention, Kennedy et al concluded that in tackling low user-engagement levels, future research should consider collaborations with existing e-health resources (Kennedy et al., 2019). By nesting BaSHH within Baby Buddy, an app with a proven track record, it is hoped that more encouraging engagement levels can be achieved.

10.4.5 Inequalities and health behaviours

Finally, it is important to remember that poor diet quality and inactivity are not simply a function of an individual's attitudes and intentions. That such behaviours are more prevalent amongst population groups living in areas of deprivation in the UK is indicative of the influence of wider societal, economic, environmental and political factors on health behaviours (Marmot, 2010). As a self-directed intervention, BaSHH requires individuals to take responsibility for their own health behaviours. However, for many these health behaviours are driven not so much by choice than by circumstances, such as living on a low income, living far from low cost supermarkets and having to rely on local convenience stores where healthier foods are less available and more expensive, having no access to open green spaces for activity and having cultural and social norms that are at odds with dietary and activity recommendations (Corfe et al., 2018). Studies in the US have shown an association between the availability of food and quality of diet, with the density of outlets selling high calorie fast food (Food Swamps) and limited access to affordable nutritious food (Food Deserts) being independently related to obesity rates (Cooksey-Stowers, Schwartz, & Brownell, 2017). Similarly, a cross-sectional study of over 50,000 adults in Greater London showed income and density of fast food outlets to be independently associated with BMI, body fat, obesity and frequent processed meat consumption, illustrating the effect of factors outside of an individual's control on their dietary behaviours (Burgoine, Sarkar, Webster, & Monsivais, 2018).

The period during which this thesis was written was one of substantial food and energy inflation with food inflation peaking at 19.2% in March 2023 (Office for National Statistics, 2024). Although the key design phases of user research (Studies 2 & 3) took place during a period of relatively low food inflation and even deflation (and consequently the 'cost of living crisis' was not a topic of discussion), the economic climate into which BaSHH will be launched and its effect on individuals' food purchasing decisions needs to be considered.

Since late 2021 rising food and fuel costs have adversely effected individuals' ability to make healthier food choices and led to rising levels of food insecurity (Tobi et al., 2023). The Broken Plate report (2023) from the Food Foundation highlighted

increasing inequalities in access to healthy foods as a consequence of rising costs, noting that the most deprived quintile of the UK population would need to spend 50% of their disposable income (after housing costs) to meet the recommended healthy diet, as per the Eatwell Guide (NHS, 2022a), whereas the least deprived quintile could achieve this with only 11% of their disposable income (Tobi et al., 2023). The authors noted that on average healthy foods were costing twice as much per calorie as unhealthy foods, with fruit and vegetables being the most expensive of the Eatwell Guide categories. When similar pressures on household budgets occurred during the recession of 2008-2009, the nutritional quality of food purchased by many households declined, with a trend towards more calorie-dense foods (Griffith, O'Connell, & Smith, 2013). The largest declines were amongst single parent families and families with young children. In the UK pregnant women and children under 4 years old can receive money to spend on healthy foods (fruit, vegetables, milk, baby formula) as part of the Healthy Start Scheme. However, this is only available to those on very low income (household monthly income of £408 or less) and who are not claiming other benefits (The Food Foundation, 2022). The current Healthy Start allowances have not been increased in line with food inflation and coupled with an average 24% increase in the cost of baby formula between 2021 and 2023, has added to the financial strain facing families with babies and young children, a proportion of whom will also be pregnant (First Steps Nutrition, 2023).

Current pressures on household budgets will make any attempts to improve dietary behaviours especially challenging. Whilst it was always the intention to design an intervention that would be relevant to the most deprived sectors of society, the prevailing economic climate emphasises the imperative of making dietary content accessible to those on very low incomes and who may have limited access to fresh foods and only basic cooking facilities. Recipes and snack ideas for BaSHH were chosen for their use of inexpensive and a small number of ingredients, as well as short cooking times. Tips were included on how to cook and eat well on a budget and challenges were selected on their achievability regardless of level of disposable income.

In conclusion, whilst a role exists for an intervention such as BaSHH that informs users about the importance of dietary and activity behaviours and encourages and supports

them to achieve positive behaviour change, policy, systems and environmental changes are needed to address systematic causes of poor health behaviours and barriers to behaviour change.

10.4.6 The opportunities and challenges of co-creation

Developing BaSHH for Baby Buddy, an existing pregnancy and parenting app was an exciting opportunity. There were substantial advantages of working with a team who had experience of developing app features and a deep understanding of their target audience of expectant parents and parents of young babies from diverse communities within the UK. First and foremost, Baby Buddy is a well-established app used widely within the NHS, meaning that BaSHH will have broad reach and potential to be a meaningful public health intervention. Secondly, Baby Buddy is trusted by its users as a source of accurate information. Credibility is an important factor in the uptake of health apps and for a new app, takes time to establish. Piggybacking on an existing app provides a 'short cut' to BaSHH establishing this credibility. Thirdly, Best Beginnings has a system for adding new content into Baby Buddy which includes an Editorial Board who review all new written and film materials ensuring it is evidence-based, relevant for the user base, and consistent with NICE and NHS advice. This process, whilst time-consuming, added a level of confidence around the proposed BaSHH content. Fourthly, as part of Baby Buddy BaSHH will be supported and maintained by Best Beginnings, thus ensuring its longevity beyond its evaluation period.

However, there were unforeseen challenges within the co-creation process and highlighting these might help others embarking on a similar journey. The first of these was the lack of clarity around funding to design and build BaSHH. At the beginning of the project there was little understanding of how complex a feature BaSHH would become. Although research costs and design work had been accounted for in early discussions with Best Beginnings, the cost of building such a multi-faceted and interactive app feature was significantly under-estimated. Thankfully we were able to secure the additional £30,000 needed through a successful grant application I submitted to The AIM Foundation. Secondly adhering to timelines was not always possible. Best Beginnings is a small, under-resourced charity and when other priorities

arose, BaSHH tended to get relegated. Thirdly, key personnel changes at Best Beginnings (including the departure of both the CEO who had initially approved this project and the head of digital who was the project lead within Best Beginnings) resulted in delays and highlighted the need for well documented records of meetings at all stages of the development process. However, overall, the benefits of working with a knowledgeable team and leveraging off the credibility and reach of Baby Buddy significantly outweighed these challenges.

10.5 Future directions

The effectiveness of BaSHH is dependent on its ability to promote behaviour change, specifically the development of healthier dietary and physical activity habits, leading to healthy weight gain in pregnancy. An RCT is the gold standard means of determining the effectiveness of the intervention. Before this can be conducted, a service evaluation and feasibility study will assess the acceptability and feasibility of BaSHH and collect preliminary data on its effect on dietary and activity behaviours. Data from this study will be used to determine whether conducting an RCT is justified. The service evaluation and feasibility study has already been designed and will take place in three test locations: Surrey Heartlands and North East London maternity hospitals and Leeds City Council districts. The protocol for this research can be found in Appendix 15.

In addition to the service evaluation and feasibility study, a number of other opportunities for further development of BaSHH will be explored. Firstly, in the course of this project we identified a deficiency of digital information and support for women who are diagnosed with GDM. A new BaSHH content pathway could be created specifically for women with GDM, with bite-size messages tailored to their needs and circumstances. Secondly there is potential to create a postnatal version of BaSHH, possibly to coincide with weening. A postnatal version of BaSHH could support and encourage new parents to establish healthier family dietary and activity behaviours. Thirdly Best Beginnings is keen to explore the potential to use the new goal setting, self-monitoring and feedback functionality that BaSHH has built into Baby Buddy to develop an intervention to support perinatal mental well-being. Fourthly, opportunities for new content and functionality to enhance BaSHH will continue to be explored, such

as the use of artificial intelligence to improve personalisation. An experimental study that randomised just under 10% of users of a smoking cessation app (n=5339/57,214) to receive an additional AI-powered chatbot feature reported that the addition of this feature doubled the engagement with the app and increased its effectiveness (Perski, Crane, Beard, & Brown, 2019). Smart chatbots are already being developed to deliver personalised pregnancy nutrition (Tsai, Kadire, Sreeramdas, Vanormer, & Thoene, 2023). Finally Best Beginnings' is committed to tackling social inequalities and as such will be exploring initiatives, including collaborations with other third sector organisations to make participation in BaSHH viable for and attractive to those from more deprived groups in society.

10.6 Conclusions

The aim of this thesis was to create an intervention to encourage healthier dietary and physical activity behaviour amongst expectant parents. As a collaboration between UCL and Best Beginnings, this work yielded important lessons on how to merge academic research methods, tools, and language with what actually works and is useful in the real-world context. The development of BaSHH adhered to a systematic approach of intervention development, drawing on empirical research and behavioural theory, whilst also listening to and reflecting the needs and views of its target users. In recognition of achieving these aims, BaSHH has now been built within Baby Buddy and will imminently be launched in three test areas in the UK. A service evaluation and feasibility study will then take place to determine the viability of an RCT to investigate its effectiveness in changing dietary and activity behaviours and reducing rates of excess GWG in the UK.

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Appendix D: Gaps in the evidence | Weight management before, during and after pregnancy | Guidance | NICE. (2010).

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Appendices

Appendix 1: Search strategy for Study 1

Example of full electronic search strategy (PsychInfo)

1. (pregnan* or gestation* or matern* or antenatal or antenatal or prenatal or pre-natal or perinatal or peri-natal).mp. (mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms)

2. pregnancy/

3. prenatal care/

4. 1 or 2 or 3

5. (diet* or healthy eating or nutrition or lifestyle or life style or physical activity or physical exertion or exercise or activ* fitness or weight gain or weight manag* or weight control).mp. (mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms)

6. physical activity/

7. exercise/

8. lifestyle/ or healthy lifestyle/

9. diet therapy/

10. body weight control/

11. body weight gain/

12. 5 or 6 or 7 or 8 or 9 or 10 or 11

13. 4 and 12

14. (((((app or apps or mobile app* or ehealth or e-health or mhealth or mobile health or m-health or internet or web or technology or smartphone or smart phone or smart-phone or cellphone or cell-phone or cell phone or mobile) adj phone) or online or on-line or text) adj messag*) or SMS or telehealth).mp. (mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms)

15. text messaging/

16. mobile application/

17. internet/

18. mobile phone/

19. e-mail/

20. 14 or 15 or 16 or 17 or 18 or 19

21. 13 and 20

22. limit 21 to (human and english language)

23. controlled clinical trial/

24. feasibility study/

25. pilot study/

26. health care survey/ or health survey/

27. (random* control* or feasibility or pilot or survey).mp. (mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms)

28. 23 or 24 or 25 or 26 or 27

29. 22 and 28

Search terms for each database

Medline

Concept 1:

Keywords: pregnan* or gestation* or matern* or antenatal or antenatal or prenatal or pre-natal or perinatal or peri-natal

MeSH: Pregnancy or Pregnant Women; Prenatal Care

Concept 2:

Keywords: diet* or healthy eating or nutrition or lifestyle or life style or physical activity or physical exertion or exercise or activ* fitness or weight gain or weight manag* or weight control

MeSH: Exercise; Life Style; Healthy Lifestyle; Body Weight; Weight Gain; Nutrition Therapy; Diet Therapy or Diet or Healthy Diet

Concept 3:

Keywords: app or apps or mobile app* or ehealth or e-health or mhealth or mobile health or m-health or internet or web or technology or smartphone or smart phone or smart-phone or cellphone or cell-phone or cell phone or mobile adj phone or online or on-line or text adj messag* or SMS or telehealth

MeSH: Telemedicine; Mobile Applications; Cell Phone; Text Messaging; Internet

Embase

Concept 1:

Keywords: pregnan* or gestation* or matern* or antenatal or antenatal or prenatal or pre-natal or perinatal or peri-natal

MeSH: Pregnancy or Pregnant Women; Prenatal Care

Concept 2:

Keywords: diet* or healthy eating or nutrition or lifestyle or life style or physical activity or physical exertion or exercise or activ* fitness or weight gain or weight manag* or weight control

MeSH: Physical activity, Exercise, Lifestyle or Healthy Lifestyle, Diet or Diet Therapy, Body Weight Gain, Body Weight Control

Concept 3:

Keywords: app or apps or mobile app* or ehealth or e-health or mhealth or mobile health or m-health or internet or web or technology or smartphone or smart phone or smart-phone or cellphone or cell-phone or cell phone or mobile adj phone or online or on-line or text adj messag* or SMS or telehealth

MeSH: Mobile Application; Mobile Phone; Text Messaging; Internet; e-mail

PsycINFO

Concept 1:

Keywords: pregnan* or gestation* or matern* or antenatal or antenatal or prenatal or pre-natal or perinatal or peri-natal

MeSH: Pregnancy; Prenatal Care

Concept 2:

Keywords: diet* or healthy eating or nutrition or lifestyle or life style or physical activity or physical exertion or exercise or activ* fitness or weight gain or weight manag* or weight control

MeSH: Physical Activity; Exercise; Lifestyle or Lifestyle Changes; Diets; Body Weight; Weight Gain; Weight Control; Health Behaviour; Behaviour Change

Concept 3:

Keywords: app or apps or mobile app* or ehealth or e-health or mhealth or mobile health or m-health or internet or web or technology or smartphone or smart phone or smart-phone or cellphone or cell-phone or cell phone or mobile adj phone or online or on-line or text adj messag* or SMS or telehealth.

MeSH: Mobile Devices or Computer Applications; Cellular Phones; Text Messaging; Internet; Electronic Communication or Computer Mediated Communication

CINAHL PLUS

Concept 1:

Title or Abstract: pregnan* or gestation* or matern* or antenatal or antenatal or prenatal or pre-natal or perinatal or peri-natal

Concept 2:

All text: diet* or “healthy eating” or nutrition or lifestyle or “life style” or “physical activity” or “physical exertion” or exercise or “activ* fitness” or “weight gain” or “weight manag*” or “weight control”

Concept 3:

All text: app or apps or mobile app* or ehealth or e-health or mhealth or “mobile health” or m-health or internet or web or technology or smartphone or “smart phone” or smart-phone or cellphone or cell-phone or “cell phone” or “mobile phone” or online or on-line or “text messag*” or SMS or telehealth

Concept 4:

“random* control*” or “control* trial” or pilot or feasibility or survey

Web of Science

Concept 1:

TS= (pregnan* or gestation* or matern* or antenatal or antenatal or prenatal or pre-natal or perinatal or peri-natal)

Concept 2:

TS= (diet* or “healthy eating” or nutrition or lifestyle or “life style” or “physical activity” or “physical exertion” or exercise or “activ* fitness” or “weight gain” or “weight manag*” or “weight control”)

Concept 3:

TS= (app or apps or mobile app* or ehealth or e-health or mhealth or “mobile health” or m-health or internet or web or technology or smartphone or “smart phone” or smart-

phone or cellphone or cell-phone or “cell phone” or “mobile phone” or online or on-line or “text messag*” or SMS or telehealth)

Concept 4:

TS=(“random* control*” or “control* trial” or pilot or feasibility or survey)

ProQuest Dissertations & Theses Global

Concept 1:

Abstract: pregnan* or gestation* or matern* or antenatal or antenatal or prenatal or pre-natal or perinatal or peri-natal

Concept 2:

Abstract: diet* or “healthy eating” or nutrition or lifestyle or “life style” or “physical activity” or “physical exertion” or exercise or “activ* fitness” or “weight gain” or “weight manag*” or “weight control”

Concept 3:

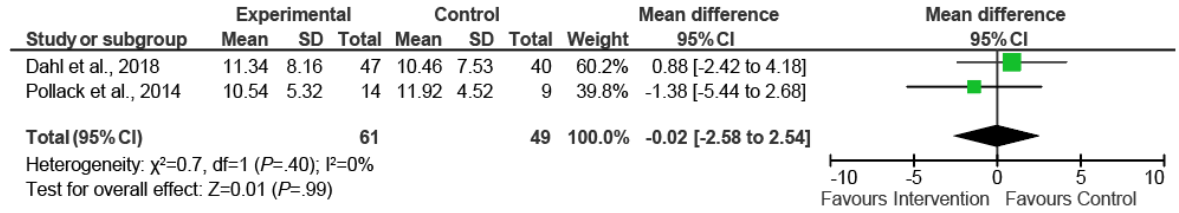
Abstract: app or apps or mobile app* or ehealth or e-health or mhealth or “mobile health” or m-health or internet or web or technology or smartphone or “smart phone” or smart-phone or cellphone or cell-phone or “cell phone” or “mobile phone” or online or on-line or “text messag*” or SMS or telehealth

Concept 4:

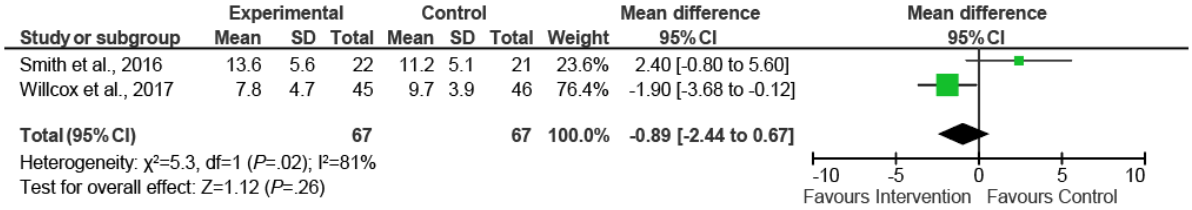
Anywhere:“random* control*” or “control* trial” or pilot or feasibility or survey

Appendix 2: Study 1 subgroup analyses

Studies where no BCTs were apparent in onboarding session



Studies where BCTs were apparent in onboarding session



Appendix 3: Study 1 BCTs by study

BCT	Effective			Non effective								
	Willcox et al 2017	Redman et al 2017	Hayman et al 2017	Evans et al 2012	Pollack et al 2014	Evans et al 2015	Smith et al 2016	Choi et al 2016	Huberty et al 2017	Olson et al 2018	Dahl et al 2018	Total
1.1 Goal setting (behaviour)	x	x	x		x		x	x		x	x	8
1.2 Problem solving	x	x	x				x	x		x		7
1.3 Goal setting (outcome)	x	x			x					x	x	5
1.4 Action planning	x		x		x					x	x	5
1.5 Review behaviour goal(s)	x	x	x									3
1.6 Discrepancy between current behaviour & goal		x										3
1.7 Review outcome goal(s)		x										1
Goals and Planning total	**5**	**6**	**4**	**0**	**3**	**0**	**2**	**2**	**0**	**4**	**3**	**29**
2.2 Feedback on behaviour	x	x	x		x			x		x		6
2.3 Self-monitoring of behaviour	x	x			x		x	x		x	x	7
2.4 Self-monitoring of outcome(s)	x	x			x			x		x	x	7
2.7 Feedback on outcomes		x								x		2
Feedback and Monitoring total	**3**	**4**	**1**	**0**	**3**	**0**	**1**	**3**	**0**	**4**	**2**	**21**
3.1 Social support	x	x	x					x	x		x	6
4.1 Instructions on how to perform a behaviour	x	x					x	x	x	x	x	7
4.2 Information about antecedents		x	x									2
5.1 Information about health consequences	x	x	x	x	x	x	x	x	x	x	x	11

BCT		Effective						Non	effective			
	Willcox et al 2017	Redman et al 2017	Hayman et al 2017	Evans et al 2012	Pollack et al 2014	Evans et al 2015	Smith et al 2016	Choi et al 2016	Huberty et al 2017	Olson et al 2018	Dahl et al 2018	Total
5.6 Information about emotional consequences	x	x	x				x		x		x	6
6.1 Demonstration of the behaviour								x				2
6.2 Social comparison	x										x	2
7.1 Prompts/cues	x							x				2
8.2 Behaviour substitution									x	x	x	3
10.9 Self-reward	x									x	x	3
12.1 Restructuring physical environment	x		x									2
15.3 Focus on past success	x											1
Total number of BCTs	**17**	**15**	**10**	**1**	**7**	**1**	**6**	**10**	**5**	**12**	**12**	

Appendix 4: Topic guide for Study 2

[NB. This was used as a guide only – the discussions were free-flowing and respondent led, although the moderator ensured all the topics were covered.]

Introductions (first names only) and brief bit about your new baby/partner's pregnancy.

(New dads/partners only) What has your experience of being a new parent been like; has it been as expected so far or what has surprised you; what have been the best/worst bits; have there been any aspects that you have found challenging; what aspects have you felt least able to cope with; do you have support when you need information, advice, a friendly ear – if so who; could challenges/problems have been avoided, if so how.

(Expectant dads/partners only) Are there aspects about being a new parent that excite you – if so what aspects excite you most and what aspects are you more nervous about; detailed exploration of all the aspects which may be causing concern and why; (probe pregnancy issues, birth, new baby, partner's and own mental and physical well-being, practical, financial, work and housing issues, relationship with partner, family and friends; what information/advice/support needs do you feel you have.

What has your experience of your partner's pregnancy been like; has it been as expected so far or what has surprised you; what have been the best/worst bits; have there been any aspects that you have found challenging; what aspects have you felt least able to cope with; who supports you when you need information, advice, a friendly ear; how would you describe your role during pregnancy and what does it involve.

Sources of information/advice/support: have you tried to get advice about pregnancy/parenthood issues – if so from where; how satisfied do you feel with these sources of advice; to what extent have you engaged with antenatal care (attendance at appointments and classes); how do you think the midwives/GPs/HCPs helped you throughout your partner's pregnancy and for parenthood; what have they done well/not

so well; what else could they do for you (e.g. partners' ant-natal course, advice on particular issues).

Interest in a dads'/partners' app: would you be interested – why/why not; what would you like to be included (explore in detail practical advice; information about partner's pregnancy; physical and mental health advice).

(Not telephone interviews) Reactions to Baby Buddy; would an app like this appeal to you; would you be happy with a female avatar/male avatar/no avatar; would you share the same app with partners – why/why not; which functions would you like to share/not to share.

How influential do you think you are in your partner's decisions in pregnancy; how do you think your behaviour affects hers.

Supporting partner: what kind of support do you think your partner needs in pregnancy; how important do you think it is to support your partner in pregnancy; what can you/do you do to support your partner during pregnancy; what can/do you do to ensure their mental wellbeing; what can/do you do to ensure their physical wellbeing; how important do you think physical activity is for your partner during pregnancy; how important do you think a healthy diet is for your partner during pregnancy; what do you know about weight gain during pregnancy; what behaviours (if any) do you think you should change during pregnancy (probe smoking, alcohol, high fat/sugar foods, takeaways etc); would you be prepared to join her in an effort to increase physical activity and eat healthily – why/why not; what might encourage you to join her (enablers); what would prevent you for joining her (barriers) (*NB consider enablers and barriers within capability, opportunity and motivation, using projective techniques such as drawings, thought bubbles etc*); which of the following dietary changes would you be prepared/not prepared/find harder/find easier to make - increase fruit and vegetable portions; replace high fat/sugar snacks with healthier snacks; reduce the number of takeaways; others.

Reactions to an app feature to help encourage healthy eating and exercise during pregnancy - you set goals, self-monitor and get feedback as well as tips and advice

on how to achieve goals; level of interest – why/why not; how would you like it to work; what kind of encouragement and feedback would you want; what kind of goals would you set; would you set goals together/compare feedback/see each other's data; would you like daily reminders and/or daily feedback; how long do you think you would sustain these changes; would they become habits; would you continue healthy eating and exercise behaviours after baby is born - why/why not.

Summary – how would you encourage dads/partners like yourselves to join your partners in improving your diet and physical activity.

Appendix 5: Topic guide for Study 3

[NB as an iterative research study, this topic guide was subject to variation]

Warm up

Tell us a little about yourself and your baby/pregnancy and your use of apps during pregnancy.

Response to the pre-task

Was it clear what this feature is all about from the pre-task materials; how would you describe it to a friend (Check that understanding is correct before proceeding and correct any misunderstanding, establishing where/how these arose).

Response to the concept of the feature

Is it something that you would/would have used – why/why not; specific likes/dislikes; motivations and barriers to usage; how you might use it/to develop which new habits; would you want to be able to follow just one stream (i.e. healthy eating or physical activity) or happy with combination?

Response to the idea of using the feature as a couple

Motivations and barriers; how would this work in practice; what bits would you do together and what would you do separately; what would you share on the app/how would you use the shared space.

Detailed evaluation of onboarding script

Was it described simply and clearly; if not which bits weren't clear/need re-wording; is the language/tone right – if not how could it be improved; is the layout clear and attractive; did they get a sense of how it would work; what do they think its purpose is; who would it be for.

Response to:

- the use of animated films
- spreading on-boarding over different days
- games to help identify healthier habits

Is the on-boarding simple enough; are there stages at which potential users may drop off, if so where and why; is there anything missing from the on-boarding; what would you call this – Getting you started/Becoming a Baby Stepper; should you earn rewards for doing this?

Is it clear at the end why it is important to take Baby Steps/make very small changes and how to set up your heathier Habits bank and Baby Steps?

SHOW BRANDING IDEAS

Response to branding ideas

Appeal of the Baby Steps name and alternative names; ideas for alternative names; appeal of visual branding – style and colours.

SHOW ALL FIGMA SCREENS

Landing page

My Healthier Habits Bank; This Week's Baby Steps; Progress Diary – do these three categories make sense - would you know what to find in each?

Detailed evaluation of the goal setting and self-monitoring features

How many Baby Steps would you want to set at any one time; what about being asked to set one diet and one exercise Baby Step? Would you want to set reminders to do the behaviour and/or to record it; interest in a reminder me again in an hour option.

Response to self-monitoring – would you want to make red go green or fill blank space with a tick; would you expect/like a little ‘fireworks’ as a celebration each time put in a tick; would you want to record anything else – like mood/feelings; would this just be a smiley face or words; what would you call this space (probe reflections)

Are these features designed in an appropriate way; is there sufficient flexibility to make the features work for you; are the visuals attractive; does it seem user-friendly; are there apps that do any of these things in a better way; are there any ways in which these features could be improved?

Feedback

Response to messages for those who have achieved their Baby Steps for the week and recorded them; is 3 variations enough and then ‘streak’ messages; response to message to those who haven’t achieved their baby step; is this motivating/helping; would it encourage you to try again or just give up.

Response to the idea of trimester feedback; what should this include over and above the weekly feedback; is this an appropriate time to encourage users to add a new Healthier Habit?

Rewards

How do users want their progress to be measured; what about the idea of collecting coloured Baby Steps/teddy bears/baby animals; should these build into bigger rewards; response to the idea of a ‘winner’ – one user (each month) with the most rewards at the end of their pregnancy gets a Tall Tape – would this increase motivation to engage/self-monitor?

SHOW EXAMPLE OF WEEKLY MESSAGES

Detailed evaluation of the 34 weekly messages, tips and challenges (a sample of each will be explored in each session)

Should users get both diet and the exercise messages or be able to opt for one or other only; what should these messages look like – short one sentence or more informative; how often should messages come – every day (you select time); every other day; once a week? are example messages interesting, relevant and motivating; is the language and tone appropriate and inclusive; ideas for things to be included in messages; response to idea of top tips; recipe of the week; active challenges; inspirational quotes.

How should expectant dads/non-birth partners messages differ from expectant mum/birth partner messages?

SHOW GILES YEO FILM

Feedback on content, tone and presenter.

Summary

Any further ideas to amend/improve the feature.

Appendix 6 : First version of onboarding scripts

Why healthier living is important.

Frame 1: Mums and dads need to be fit and healthy - being a parent is hard work and a whole lot easier if you are healthy and full of energy.

Frame 2: A nutritious and varied diet and being active reduces your risk of heart disease, diabetes, cancer, dementia and is generally good for your mental well-being.

Frame 3: Keeping active and eating well can help keep weight gain during pregnancy at a healthy level and help avoid complications like GDM. This means you will be in better shape for labour and being a new parent.

Frame 4: A nutritious diet is important for baby's growth and development in the womb and their health as a child and adult. Women who eat a healthy and balanced diet and avoid putting on too much weight during pregnancy reduce their baby's chances of weight-related illnesses later in life. So concentrate on eating well and keeping active for a healthier pregnancy, healthier baby and a healthier family life.

What is a healthy diet?

Frame 1: Healthy eating is not about following any particular diet but rather making sure your diet is full of nutritious foods and lite on those foods that might taste nice, but don't do us any good at all. Our 5 golden rules are:

Frame 2: 1. Eat lots of vegetables and fruit every day. You've probably heard of the five a day (eating at least five portions of fruit and vegetables a day) - this should be your minimum – aim higher 7 even 10 portions a day and go for variety -different types and different colours of fruit and veggies. If you're feeling hungry or your plate looks a little empty – fill up with veggies. Fruit and vegetables don't have to be expensive and don't have to be fresh to be good for you. Beans and pulses (like lentils, chickpeas even baked beans) count and they are a great source of protein too. And if you're not a veggie lover, don't worry, we have tips for you!

Frame 3: 2. Choose unrefined foods over refined foods. Refined foods tend to be heavily processed or altered foods whereas unrefined foods are those that are in or close to their natural state. Refined foods often have sugar, salt, fats or preservatives added to them to make them taste more appealing and last longer. Some examples of refined foods are white bread, breakfast cereals, pork pies. Try to go for fewer processed foods that have been made in a factory and swap the white products like bread, rice and pasta for brown, wholegrain versions. This way you get all the important fibre.

Frame 4: 3. Limit the amount of animal fat foods you eat. This means cutting back on fatty meats and cheeses, butter and cream and trying to swap to healthier proteins and fats such as olive oil, fish, eggs, Greek yoghurt and tofu.

Frame 5: 4. Keep foods and snacks that are high in sugar, salt and fats such as crisps, biscuits, cakes, chips, burgers and pizzas for occasional treats only. These foods give you the calories but without the nutritional goodness that you and your baby) need.

Frame 6: 5. Say no to sugary drinks. There can be round 10 teaspoons of sugar in a can of fizzy pop. Too much sugar leads to weight gain. It’s also bad for your teeth. Hormones during pregnancy can lead to gum disease and tooth decay, so looking after your teeth is particularly important during pregnancy.

What does keeping active mean?

Frame 1: For most of us it simply means moving more. Guidelines say 150 mins of moderate to vigorous activity a week- that's when you feel your heart rate increasing or you have to breathe harder.

Frame 2: If you are there already - great stuff - see if you can maintain this throughout your pregnancy. If you aren't there already, start slowly and build up the exercise or activity you do and if in any doubt about what you should be doing, check with your GP or midwife first.

Quizzes to check learnings.

So just to recap on our main messages today:

Eating a healthy and nutritious diet in pregnancy and keeping active is important because it:

Tick all that apply:

Reduces the risk of complications during pregnancy and labour.

Ensures you are providing the nutrients baby needs to grow and develop.

Prevents you gaining an unhealthy amount of weight.

Protects you and your baby against future weight related health problems such as diabetes, heart disease and cancer.

Prepares you to be a fit, active and healthy parent.

To eat a healthy and nutritious diet it is important to:

Tick all that apply:

Eat lots of vegetables and fruit.

Choose unrefined or foods in their natural form over refined and processed foods.

Limit the amount of animal fats you eat in favour of healthier plant or fish options.

Keep food and snacks that are high in sugar, fat or salt for special occasion treats.

Cut out sugary drinks.

Staying active during pregnancy means:

Tick all that apply:

Keeping moving!

Avoid sitting down for too long.

Aim for at least 150 minutes a week of moderate activity where you feel your heart beating faster and you breathe harder.

Day 1/2 How to succeed in making healthier changes

Frame 1: We are going to guide you through a tried and tested approach to building healthier habits so that when baby arrives you will be well on the way to living a healthier life. We are going to ask you to imagine what kind of future you want for you and your family and help you identify what changes you need to make to your lifestyle to achieve that future. Then we are going to show you how by taking really small steps – in fact Baby Steps, you can make those changes.

Frame 2: We will be with you to inspire and support you on your journey, with weekly information, extra challenges and tips. You will also find loads of easy and inexpensive recipes and snack ideas as well as exercise ideas from single exercises through to 30-minute work outs.

Frame 3: Making changes to your lifestyle is not easy - we need to break old habits and cut down on or even give up some of the things we love and start doing things we make not enjoy as much. However if you do this with someone else, you will find it a whole lot easier and much more fun! You can support each other especially when one is struggling – so get your partner, your mum or a friend on board. Studies have shown people are much more likely to succeed in making the changes they want to when they have support from others.

Frame 4: We are going to set you the task of thinking about what kind of healthy family lifestyle you want for your baby to grow up in. You can draw a picture or write a description or find some photos that capture what you are aiming for. You can use this space to save your ideas. We are going to call this your vision/future us/my healthy family and it is important as we shall come back to this in the months that follow. *“A*

vision is not just a picture of what could be; it is an appeal to our better selves, a call to become something more." (Rosabeth Moss Kanter)

Day 2/3 (Creating healthier habits)

Frame 1: Congratulations on creating your vision. Remember you can go back to this space to add any thoughts and feelings you want to through this journey.

Frame 2: Now we need to work out how to make My Healthy family a reality - which healthier habits you need to develop to achieve your vision. It's important to remember, you will only succeed in developing healthier habits if you really want to make these changes and you find them easy to do. We are going to take you through a 3-step process to help you work out the best healthier habits for you to aim for.

Exercise: Step 1: Let's start by thinking of all the healthier habits could commit to. Here are some of our ideas which you could use or better still, choose your own.

Exercise: Step 2: card sort 1 to divide into ones that would best help me achieve the Future Me/Us

Exercise: card sort 2 to divide into ones I can and want to achieve

From this pile we recommend you choose your first healthy eating and your first exercise habit

Day 3/4 (Baby Steps)

Frame 1: Congratulations! You have decided on the first healthier habits you want to tackle. Now we will show you how to make it easy with our Baby Steps approach - making little changes that grow into bigger changes.

Frame 2: When we decide to make changes in our lives, we often set ourselves very high targets and then find we just can't achieve them, so we give up (anyone who has been on a diet will recognise this).

Frame 3: A much better way to develop healthier habits that will stick is to make little changes or Baby Steps – so small that they are easy to do and when you feel ready, you can add another Baby Step towards your targeted healthier habit. And each time you succeed in taking a Baby Step, you will get that feel good feeling of success that will spur you on.

Frame 4: Here's an example: if your goal is to eat 5 portions of fruit or veg a day, but at the moment you barely scrape one, don't try for 5 right off. Maybe see if you can add one more portion of veggies to your evening meal on Thursdays. When you are happy doing this, maybe add another day and/or another portion and build up this way over time.

Frame 5: Or another example: if you're not a very active person, but want to start being more active, don't set yourself the goal of going to the gym 3 times a week. Rather think about maybe doing 3 swats while you are brushing your teeth. Maybe after a few days you can add some more, or you could add a lunge or two while the kettle is boiling. You can read here about how taking baby steps like these has worked for others. (Click here to read about what X did)

Exercise: Here's a 3-step process to design your first Baby Steps

Step 1: Decide what - think of the smallest version of your healthier habit and call that your Baby Step. It could be eating one carrot or even having one bite of carrot. Remember go small – you can always do more than one step at a time, but you want to make sure that even on bad days, your Baby Step is something you can do.

Step 2: Decide when - when in your day you are going to take this Baby Step. If you are swapping a behaviour, like trying to eat a piece of fruit rather than a biscuit, then it will be easy to know when (when you reach for a biscuit). If you are trying to add a new behaviour, for example do some exercise, the best way to remember to do a new behaviour is to attach it to another daily/regular behaviour like brushing your teeth, checking your emails, boiling the kettle.

Step 3: Choose a way to celebrate your success: We all feel good about ourselves when someone congratulates us for what we have done, so remember to congratulate yourself and each other if you are doing this together with a partner/friend. This is really important because feeling good about the changes we make encourages us to stick with them and do more. So choose how you want to celebrate. You could a little jump in the air, say ‘well done me/us’, pat your bump to high 5 your baby, do a little whoop!, look at yourself in a mirror and give yourself a thumbs up.

Well done! Now we want you to record your first Baby Steps After/Instead of X I will Y and celebrate with a Z

Day 4 (Prepare and practice)

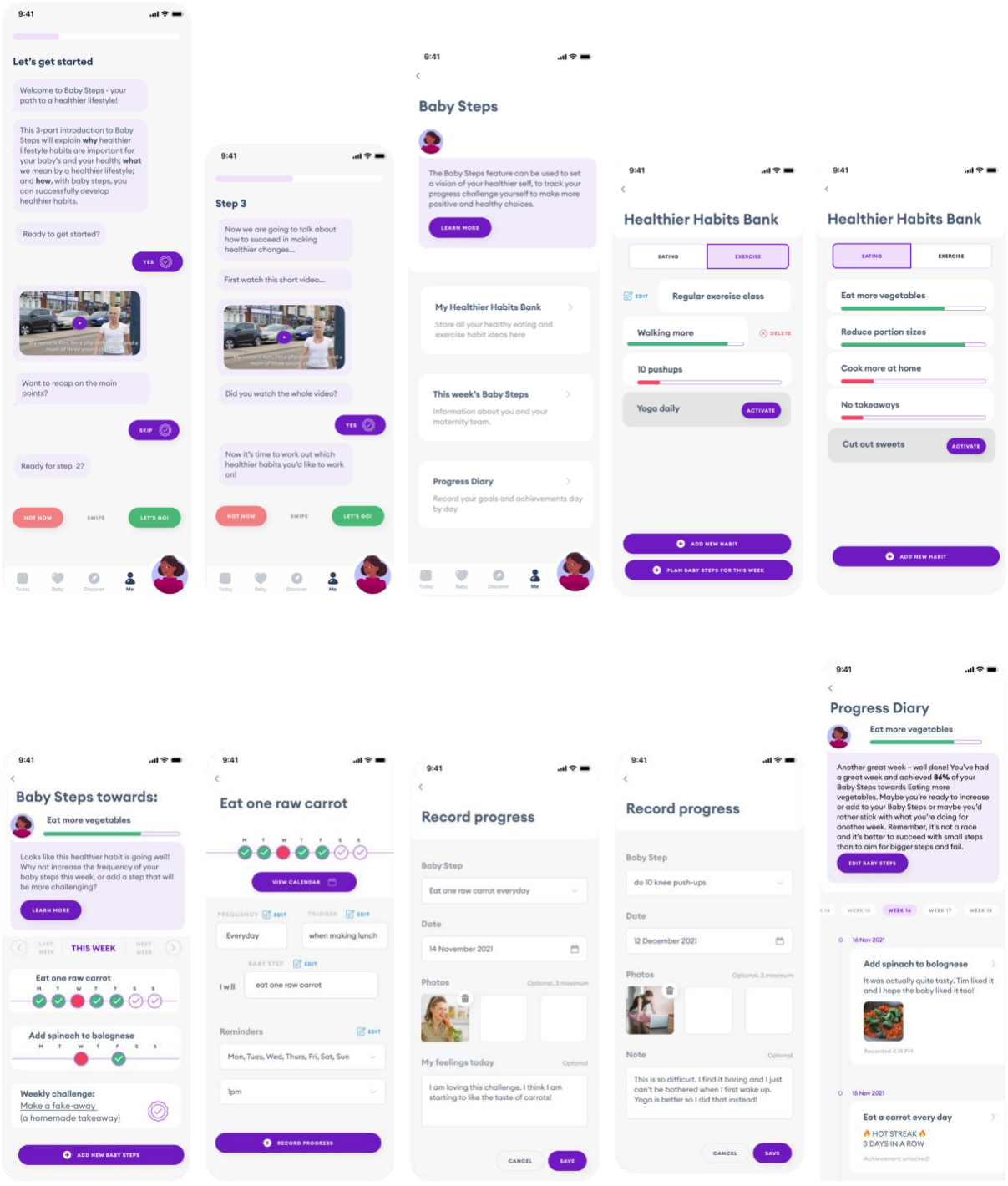
Frame 1: Preparation is key to success: The best chefs get all their ingredients together, weighed out and ready before they cook, and this is what you should be doing to make your Baby Steps easy to do.

Frame 2: If you are trying to swap biscuits or crisps for healthier snacks, make sure you have those on your shopping list and at home and stop buying the unhealthy snacks – get temptation out of the way! Even putting the unhealthy foods on the top shelf or the back of the fridge and moving the healthy ones to where you look or reach first can help you on your way.

Frame 3: If you want to increase your daily step count, make sure you have comfy shoes and that they are ready to slip on by your front door.

Frame 4: And it’s important to practice. So try out your healthier habits now –see how it feels, make it familiar, practice your celebration and get ready to start tomorrow

Appendix 7: Study 3 wireframes



Appendix 8: Examples of first draft bite-size messages

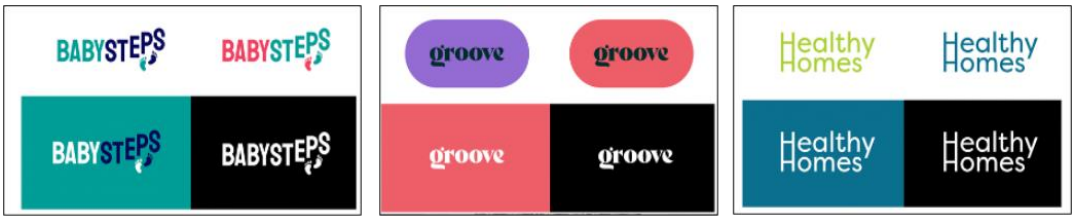
Top Tips: Eating	Top Tips: Activity	Midweek messages	Partner messages
Is pregnancy messing with your appetite? Some women feel hungrier while others suffer nausea or sickness and only want beige foods like mashed potato and biscuits. Top Tip: Keep some healthier snacks to hand for when hunger strikes or nausea means you can't face a proper meal. Check out super snack swap ideas here	Top Tip: Some people find that tracking their steps on their phone helps motivate them to move more. Many phones have an inbuilt step counter or download Active 10 - a free NHS approved app to help you stay moving! (Link to Active 10)	Homemade soups are a great way of getting your 5 a day when you're not feeling like proper meals and easy to make yourself. And you can spice them up or down depending on how you feel. Check out some of our simple speedy soup ideas here.	Being pregnant has all sorts of effects on your partner's appetite - she may be feeling nauseous or being sick, she may start to feel extra hungry or she may have gone off certain foods. Trying to eat well can be extra challenging so kindness, encouragement and support is what's needed. How can I help? Work out what healthy, nutritious foods and snacks she likes and make sure they are always available.
Have you heard the phrase overfed and undernourished? Today's food environment makes it easy to eat too many calories without getting the nourishment we need. Top Tip: Follow the Eat well in pregnancy guide (here) to help you and your baby get the nourishment you need.	Believe it or not, most of us could breathe better! Breathing well can help us relax and sleep better and help us get the most out of our exercise and activity. Check out more on breathing well and our simple breathing exercises here. Top Tip : If you are feeling stressed or can't sleep, try 4 rounds the 4-6-8 breathing - breathe in for 4 counts, hold for 6 counts and breathe out for 8 counts.	Check out your drinking habits too (no, we aren't talking alcohol here). It's easy to ignore the sugar and calories we consume in drinks. Wherever possible, go for low or no sugar options. Top Tip if you want to reduce sugar in tea or coffee do it half a teaspoonful at a time (Baby Steps again), so you barely notice the change and you will find it easier to reach the sugar-free target.	Both mum and baby need a nutritious diet to thrive during pregnancy. Making healthier choices is not always easy. How can I help? Support her to eat a nutritious food by doing so yourself - you will also benefit from eating well.
As your baby's organs are developing it's important that he/she/name gets the nutrients he/she/name needs. Find out more here Top Tip: Nutrient rich foods need not be expensive - tinned or dried chickpeas, kidney beans and lentils, fresh or frozen spinach or kale are great options for this stage of pregnancy. Check out our recipe ideas here.	Up your active! Being more physically active doesn't mean having to go to the gym although please do if you enjoy it). Why not think about it as trying to spend less time sitting or standing still? Top Tip: Move more by adding several easy little moves into your day rather than always aiming for the big one. Click here for some of our ideas	Recent research suggests that many pregnant women don't have enough iron rich foods in their diet which can cause health problems for mother and baby. Check out our list of iron rich foods here and see if you can include more in your diet.	is it safe for her to exercise? Yes and it is important for her health and baby's well-being. Obviously it's important to exercise safely, check out our guides to being active in pregnancy here.

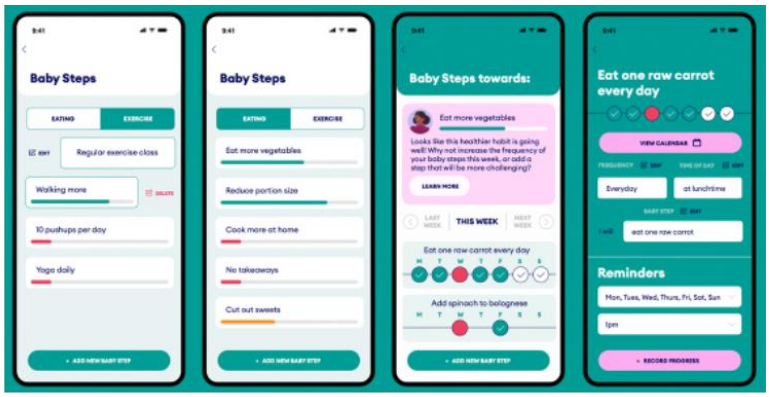
Top Tips: Eating	Top Tips: Activity	Midweek messages	Partner messages
Cooking your own meals using 'real' foods is the best way of getting you the nutrition you need. Ready prepared food and snacks (often called Ultra processed food) provide little if any goodness for you or your baby and there is growing evidence of them causing harm to your health. Find out more about what ultra-processed foods are and why they are bad for you here. Top Tip: Use your pregnancy as a time to develop your cooking skills and build a bank of easy, quick, nutritious meals you really enjoy. Check out our recipes for inspiration	Exercising at home means you can do it when you want, wear whatever or as little you want and can sing along loudly to your favourite soundtrack. Check out some of our homework outs designed especially for your stage of pregnancy here. Top tip: Plan and prepare - make sure you have the right space for your workout and plan when you are going to do it.	It takes time to adjust to new tastes, so if you are trying snack swaps give yourself time to get used to them.	As baby's organs are developing in 1st trimester, it's important that he/she gets important nutrients. including folic acid, iron, iodine. Sounds complicated but there are plenty of relatively inexpensive foods are full of these important nutrients such as lentils, spinach, kidney beans, kale, beetroot. How can I help? If you aren't already, get involved in the cooking learn some easy, nutrient rich recipes you'll both enjoy. Check out our recipes here
Planning is important. Research shows that you are more likely to make healthy choices if you plan your meals in advance and shop with a list. You'll also find you waste less this way. Top Tip: Make a weekly meal plan - check out our recipes for inspiration	Research shows that people tend to be more active if they hang out with active people - so find your active friends! Top tip: plan and commit to a regular activity with your partner or a friend - you're less likely to find an excuse not to if someone else is involved	It can be helpful to stick a post-it note on your computer screen or next to your TV to remind you to do your Baby Step, especially in the early days when it's easy to forget.	Keeping active is important for all of us and just as important during pregnancy. How can I help? Support her to keep active by doing active things together - going for a walk, going swimming or even dancing in your living room

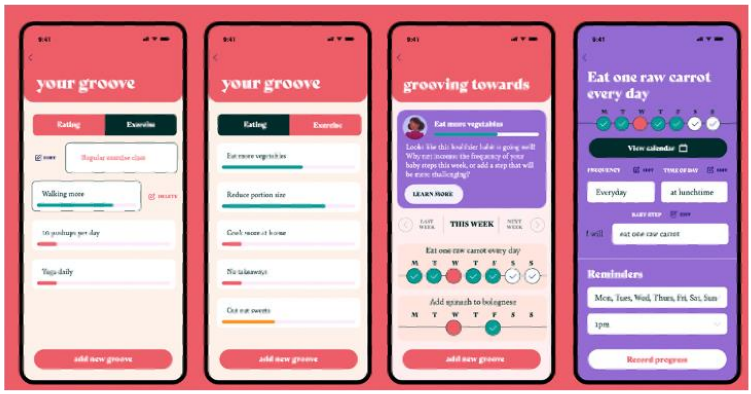
Top Tips: Eating	Top Tips: Activity	Midweek messages	Partner messages
Not all bugs are bad news. We have millions of good bugs in our stomachs - that's the gut microbiome. It helps keeps us healthy, fights diseases and supports good mental well-being. Learn more about the gut microbiome here. Top Tip: The best way to a healthy gut microbiome is to eat a rainbow...not literally - just a colourful mix of vegetables and fruits. Check out our veggie colour chart for inspiration.	By now your baby weighs the same as a dessert spoonful of baked beans. When he/she is born he/she will probably weigh the same as at least 6 tins of baked beans. Building up your arm muscles now will mean you'll be ready for all the lifting, carrying and cuddling to come. Top Tip: Tins of beans, bags of sugar, rice etc make great weights for arm exercises in the kitchen. Check out our simple arm exercises here	If you're not a fan of veggies, look at our tips on pain-free ways of getting them into your diet.	Not all bugs are bad news. We have millions of good bugs in our stomachs - that's the gut microbiome. It helps keeps us healthy, fights diseases and supports good mental well-being. And to keep those good bugs happy, we ned to feed them plenty of vegetables
Does fat make you fat? Well not always. There are good fats like those found in salmon, sardines, eggs and walnuts and bad fats found in lard, butter and red meat. Watch this short video to hear more about good and bad fats. Top Tip: Fresh fish can be very expensive, but tinned tuna and sardines contain the good fats too.	Making healthier changes is not easy, but don't be hard on yourself if some days you stumble over your Baby Steps. Top Tip: Think how you would talk to and encourage a friend and be that kind to yourself.	Good fats are not only good for your and baby's health, but also will help you stay fuller for longer. Check out some of our meal and snack ideas for keeping full for longer here	Fat is not always bad for you. Good fats are important for everyone's health including your baby's. Challenge: See if you can add one of our good fat recipes (here) to your recipe collection.

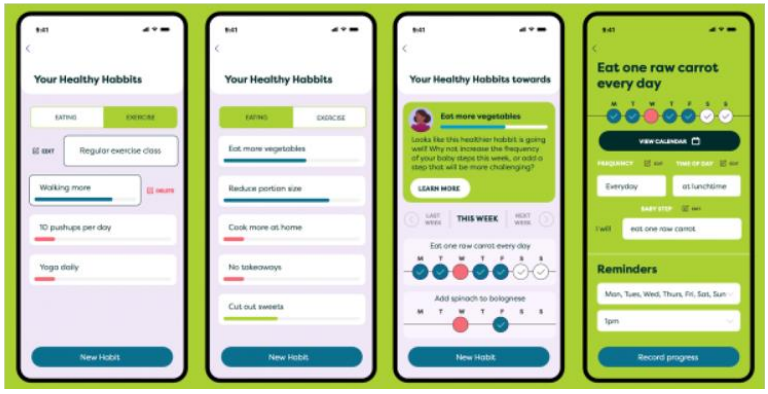
Appendix 9: Branding ideas

Examples shown to participants in Study 3[6]









[6] Healthy Homes was revised to Healthy Habbits early on in the research process.

Appendix 10: British South Asian sub-study: summary of themes

Four themes were identified in this sub-study, describing the views and experiences of British South Asian expectant parents to dietary and physical activity behaviours in pregnancy and their response to the intervention concept. These are summarised as follows:

1. Influence of family and community advice

Participants described receiving advice on their behaviours in pregnancy from the female members of their family, most notably their mother and mother-in-law, and the wider female South Asian community, especially 'Aunties' - typically friends of their parents. Advice appeared to be valued more when it was passed on from women whose circumstances were similar to theirs and who had had similar experiences during pregnancy. Participants also spoke about their partners being influenced by the advice of this matriarchal group.

- Diet: Advice had been received on foods that should and should not eaten during pregnancy. Some foods that were commonly reported as 'bad' in pregnancy were pineapple, papaya and seafood. Some women had been told to eat specific foods at particular stages of their pregnancy to keep the baby healthy, to avoid nausea and to induce labour. The majority of participants had been encouraged to eat more as they were now 'eating for two'.

- Physical activity: Many had been advised to perform less 'strenuous' physical activity, like yoga or walking, as they should be 'taking it easy' during pregnancy.

2. Concerns about contradictory advice

Advice participants had received from family members and the wider community had not always been consistent with advice received from HCPs. This could be a source of anxiety during pregnancy and participants sort to resolve discrepancies by Googling or referring to pregnancy-specific websites like "What to expect when you are

expecting” and the NHS. Having a trusted and credible source of advice was therefore valued.

3. Fear for the mother’s health

There was a common consensus that baby’s health and development was the prime concern, many participants voiced concerns they had had over their own health. For some this was as a consequence of a bad experience, whereas for others it was based on an awareness of a higher prevalence of comorbidities during and after pregnancy among South-Asian women. was the biggest motivator for them to engage in building healthier habits. For many participants, the fear of developing complications during or after pregnancy had been a significant motivator to adopt a healthier diet. However, fear for their own health outcomes could impede engagement in physical activity.

4. Inclusivity at first glance

For the feature to be culturally sensitive and inclusive, participants expected it to communicate such at first glance. Accordingly, content such as background images, recipes and physical activity challenges were expected to be obviously diverse.

- Participants wanted to see images of Asian women, including those wearing a hijab in the feature.
- They also wanted to see culturally inclusive recipes that were authentic rather than anglicized versions of Asian dishes.
- References to the festivals that affect dietary patterns, such as Diwali and Ramadan, were also expected.

Appendix 11: Summary of findings from midwife interviews

Midwives responded enthusiastically to the intervention concept:

Regular midwives:

- Welcome the prospect of delegating to this intervention as they don't have time (to talk at length about diet and exercise.
- See this as a way of avoiding or reducing the awkwardness/embarrassment of discussing diet and weight with pregnant women.
- Enthusiastic about the idea of access to the latest and/or specialist dietary and physical activity recommendations as not always sure themselves.

GDM and 'at risk' midwives:

- Perceive this as another way of supporting mums and reinforcing the important messages about healthy eating and physical activity.
- Welcome behaviour change/habit formation element as this is outside their scope.
- Want an in-app shared space to support a cohort.
- Would also like advice on low GI foods/diets.

Appendix 12: Extract from the Table of Changes

Content	Positive Comments	Negative Comments	Possible Change	Reason for change	MoScoW
Onboarding	Recognises the challenges facing pregnant women	Feels aimed at first time parents	Include more references to additional challenges of having other children/toddlers	IMP	MUST do
Onboarding	Explains why healthy eating and PHYSICAL ACTIVITY are important now to mother and baby	Distal health benefits are not especially motivating	Focus on proximate benefits to mother's and baby's health	IMP	MUST do
Weekly messages	Tips, unusual facts and challenges are liked	Once a week is not enough	Consider more frequent messaging	REP	SHOULD do
Weekly messages	Bite-size messages are good	Some messages are too long	Cut down longer message even further	REP	MUST do
Dietary messages	Relevant to most	Not always appropriate for women with GDM	Consider additional messaging for women GDM	NCON	COULD do
Self-monitoring	Good to have reminders		Would like a 'remind me later' option	NC	SHOULD do
Rewards	Nice to have achievement recognised	Virtual rewards are only virtual	Would like real value rewards/	NCON	WOULD like

	Even nice emojis – just makes you feel you've achieved something. (FEMALE #5		discounts on healthy foods		
Branding	Baby Steps fits with Baby Buddy and communicates the method, little feet logo appeals	Other brand names/logos have limited appeal	Go with Baby Steps	REP	SHOULD do

Abbreviations:

MoSoCoW: MUST do, SHOULD do, COULD do, WOULD like; IMP: Important for behaviour change/Guiding Principles; EAS: Easy and uncontroversial to change; REP: Repeatedly said in research; EXP: Supported by experience from PPIE/experts/literature; NCON: Does not contradict Guiding Principles; NC: Not changed; GDM: GDM; M: male; F: female

Appendix 13: Summary of BCTs in BaSHH

Feature	BCT
Onboarding	1.1 Goal setting (behaviour) 1.4 Action planning 5.1 Information about health consequences 5.6 Information about emotional consequences 8.1 Behavioural practice/rehearsal 12.1 Restructuring the physical environment
Healthier habits and baby steps	1.1 Goal setting (behaviour) 1.4 Action planning 7.1 Prompts/cues 8.2 Behaviour substitution 8.3 Habit formation 8.4 Habit reversal 8.7 Graded tasks
Habit buddy	3.1 Social support
Record a baby step	2.3 Self-monitoring (behaviour)
Weekly feedback	1.2 Problem solving 1.5 Review behaviour goals 1.6 Discrepancy between current behaviour and goal 2.2 Feedback on behaviour

	15.3 Focus on past successes
Journal	1.9 Commitment 9.3 Comparative imagining of future outcomes 13.5 Identity associated with changed behaviour
Awards	10.1 Material incentive (behaviour) 10.2 Material reward (behaviour)
Bite-size messages	4.1 Instructions on how to perform a behaviour 5.1 Information about health consequences 5.6 Information about emotional consequences 8.2 Behaviour substitution 12.2 Restructuring the social environment 13.1 Identification of self as role model
Exercise videos	4.1 Instructions on how to perform a behaviour 6.1 Demonstration of behaviour 6.2 Social comparison
Recipes	4.1 Instructions on how to perform a behaviour
HCP videos	9.1 Credible source
Peer to peer videos	6.1 Demonstration of behaviour 6.2 Social comparison

Appendix 14: Feedback messages

Feedback messages -success (> 85%)

- Well done! You've had a great week and achieved x/y of your baby steps. You might be ready to increase one of your baby steps or add a new one. Remember one step at a time and keep it small to keep winning!
- Two weeks in a row – great job! This week you have achieved x/y of your baby steps. You are well on your way to developing a new habit. Are you ready to increase one of your baby steps or add a new one? If not, just stick with and strengthen this step for another week.
- Three week streak! You're acing this. If you feel confident, now might be the time to increase your baby step or add a new one.

Feedback messages – mid range (41% - 84%)

- Well done – you're making progress! This week you have achieved x/y of your baby steps. Remember, even the smallest baby step will be beneficial for you and your baby/name.
- Good work! You've achieved x/y of your baby steps. Maybe it's been a tough week and you've achieved this despite challenges. If so, congratulations! Maybe you feel you could have done better but be kind to yourself and remember any progress is good progress.
- Well done - you've achieved x/y of your baby steps this week. See if you can play your own detective and work out how you can improve your success rate. Are you asking too much of yourself? Can you make your baby step even smaller/easier? If you're just forgetting to do your baby steps, link your them to something you already do on a regular basis or maybe set yourself reminders.

Feedback messages - low range (<41%)

- Well done - you've achieved x/y of your baby steps this week. Maybe you've had a particularly challenging week or maybe there have been other reasons for you not completing more of your baby steps. Be kind to yourself, next week

is a new week and even the smallest baby step you take will be beneficial for you and your baby/name.

- *(Same as 6.)* Well done - you've achieved x/y of your baby steps this week. See if you can play your own detective and work out how you can improve your success rate. Are you asking too much of yourself? Can you make your baby step even smaller/easier? If you're just forgetting to do your baby steps, link your them to something you already do on a regular basis or maybe set yourself reminders. You can look here at tips for success.
- Well done -you've achieved x/y of your Baby steps this week. If you are struggling, think what you might say to a friend who was struggling to make the changes and take your own advice. Alternatively try talking with your partner/baby steps buddy/name and see if they have any ideas on how to get back on track with your healthier habits.

Feedback messages 0%

- You haven't recorded any baby steps this week. Maybe you forgot to record them and you are actually acing this or maybe you're struggling to make the changes. Don't despair – see if you can manage one tiny baby step next week.
- You haven't recorded any baby steps this week. See if you can play your own detective and work out how you can improve your success rate. Are you asking too much of yourself? Can you make your baby step even smaller/easier? If you're just forgetting to do your baby steps, link your them to something you already do on a regular basis or maybe set yourself reminders.
- You haven't recorded any baby steps this week. If you are struggling, think what you might say to a friend who was struggling to make the changes and take your own advice. Alternatively try talking with your partner/baby steps buddy /name and see if they have any ideas on how to get back on track with your healthier habits.

Movement messages:

- Well done – you're back on track! This week you have achieved x/y of your Baby steps. Keep going and see if you can manage 2 weeks in a row.

- Well done – you’re on the up! This week you have achieved x/y of your Baby steps. Keep going and build on your success next week.

Appendix 15: Baby Steps to Healthier Habits: service evaluation and feasibility study protocol

Abstract

Baby Steps to Healthier Habits (BaSHH) is a digital intervention to support the development of healthy dietary and physical activity habits during pregnancy. The intervention has been developed for the Baby Buddy pregnancy and parenting app hosted by the UK charity Best Beginnings. It will initially be available to all Baby Buddy users within Leeds City Council districts, and Surrey Heartlands and North East London NHS maternity hospitals as part of standard antenatal care. The overall objective of this study is to assess the acceptability and feasibility of BaSHH and to collect preliminary data on its effect on dietary and activity behaviours and GWG. Study data will also be used to determine if the intervention is scalable and, if so, whether conducting an RCT is justified.

A mixed methods approach will be applied to this service evaluation study, combining quantitative in-app surveys measuring user experience, dietary and physical activity behaviours, with qualitative interviews exploring user experience of BaSHH and experience of study participation. In addition, aggregated and anonymous in-app data will be used to measure breadth and depth of user engagement with the digital intervention elements. Quantitative data will be analysed in SPSS. Paired tests will be used to measure changes in dietary and activity behaviours. Qualitative data will be analysed thematically.

Background

Maternal obesity and excessive gestational weight gain (GWG) are independently associated with adverse maternal and foetal health outcomes during pregnancy and birth. Excessive GWG also increases a woman's risk of postpartum weight retention (Nehring et al., 2011) and her chances of starting a subsequent pregnancy with overweight or obesity (Gilmore et al., 2015). Moreover, there is building evidence that poor maternal diet and excessive GWG predispose offspring to a life-long risk of obesity through epigenetic programming (Ohlendorf et al., 2019; Voerman, Santos, Patro Golab, et al., 2019). Pregnancy is a time when many women are motivated to improve their health behaviours for the sake of their unborn child (Phelan, 2010). An intervention to encourage the development of healthy dietary and physical activity habits during pregnancy might therefore have potential to prevent excessive GWG and protect against obesity-related health risk for parents and their offspring.

To date lifestyle interventions to encourage healthy eating, physical activity and weight management in pregnancy have shown modest effects in reducing GWG, (International Weight Management in Pregnancy (i-WIP) Collaborative, 2017). Fewer have reported on changes in these energy balance behaviours, especially in the longer term. More recently interventions have embraced digital technologies either as an exclusive delivery method or to support in-person delivery of dietary and physical activity advice. Whilst research data show digital interventions to be less effective than those delivered in-person, several digital interventions have been successful (Sherifali et al., 2017; Walker et al., 2018). Importantly, digital delivery offers significant advantages of broader reach and lower delivery costs (Bailey et al., 2020).

Baby Steps to Healthier Habits (BaSHH) is a newly developed digital intervention to encourage and support expectant parents to develop healthier dietary and physical activity habits. It is rooted in behaviour change theory and habit theory (Rhodes et al., 2021) and PBA to its development has ensured that it reflects the needs and views of target users (Bradbury, Morton, Band, Van Woezik, et al., 2018). The intervention is nested within Baby Buddy, the free, NHS approved pregnancy and parenting app from UK charity Best Beginnings. Consistent with its parent app, BaSHH has been designed with a particular focus on the socially and/or economically disadvantaged, who are

more likely to face health risks from poor dietary and physical activity behaviours. Initially the intervention will be available only to Baby Buddy users in three localities, Surrey Heartlands and North East London NHS maternity hospitals, and Leeds City Council, in order to conduct a service evaluation study to explore its feasibility, acceptance and effectiveness. This document outlines the protocol for the service evaluation study.

Aims

The overall aim of the service evaluation study is to explore the feasibility and acceptability of BaSHH and to provide preliminary data on its effectiveness. The findings will be used to guide improvements and amendments to the intervention and determine the feasibility of conducting a randomised controlled trial (RCT).

The specific research objectives of this service evaluation are as follows:

- To investigate users' experience of BaSHH determining its suitability in addressing their information and support needs and identifying where improvements to the content or user experience could be made.

- To explore level of user engagement with the intervention and identify facilitators and barriers to engagement/greater engagement.

- To provide preliminary data on the profiles of those who engage in the intervention, and its overall reach.

- To assess the effectiveness and ease of the study recruitment procedure.

- To assess study attrition rates and to understand reasons for drop-out.

- To assess the suitability and functionality of the data measurement tools, identifying any barriers to or problems with completing the study questionnaires.

- To provide preliminary data on the intervention's effect on changes in dietary and physical activity behaviours.

These data and insights will be used to refine BaSHH and determine the feasibility of conducting a fully powered RCT to assess its effectiveness.

Methods

Study setting

The study will be conducted in Surrey Heartlands and North East London maternity hospitals and Leeds City Council districts. BaSHH will be accessible to all antenatal Baby Buddy users within these localities as part of their standard antenatal care.

Study design

The study will use a mixed methods approach, combining quantitative in-app surveys, qualitative interviews and statistical analysis of aggregated and anonymous in-app data.

Quantitative in-app surveys at five time-points will provide feedback on the user experience as well as changes in dietary and physical activity behaviours.

Qualitative interviews will be conducted with a sub-sample of study participants at two time-points. These will explore user experience in more depth and will also examine experience of participating in the service evaluation study. This sample will include those who have stopped using BaSHH and/or dropped out of the study. Where partners have participated in the intervention, couple interviews will be conducted.

Aggregated and anonymous in-app data will be analysed to provide insight into engagements levels. Depth of engagement will be measured by frequency of clicking on app pages and using specific features including goal setting and self-monitoring. Breadth of engagement will be measured by the proportion and demographic profile of Baby Buddy users using BaSHH.

The BaSHH Intervention

BaSHH is an intervention to encourage and support the development of healthier dietary and physical activity habits, nested within the Baby Buddy app. BaSHH delivers gestation-age-appropriate healthy eating and activity information, tips and ideas across 32 weeks of the intervention program. An onboarding procedure explains to potential users how to choose healthier habit goals and break these down into small, manageable, incremental changes or baby steps. The program allows users to record their baby steps and weekly personalised feedback messages, based on tracking data, will serve to encourage users on their baby steps journey. Users are encouraged at the onboarding stage to link to their partner's or another buddy's Baby Buddy app to share their BaSHH journey. The non-pregnant partner/buddy will receive one weekly message with content similar to that of the pregnant partner, with additional tips on how best to provide support. Users can choose to share additional content and personalised feedback data with their partner/buddy if they wish to.

Study participants

Participants will be adult (>18 years old) pregnant women of all BMIs (body mass index, calculated as weight divided by height squared), and their partners, where relevant. Those under 18 years of age or without a mobile phone or sufficient English to understand the intervention will be excluded. Broad quotas on age, socio economic status, ethnicity and BMI will ensure diverse insights. At screening, a measure of food insecurity will also be taken using the Food Insecurity Experience Scale to ensure a representation of participants experiencing food insecurity (Cafiero, Viviani, & Nord, 2018).

Sample sizes

Recommendations for feasibility studies suggest that a minimum of 30 participants is required (Lancaster, Dodd, & Williamson, 2004). Whilst the study is not designed nor powered to test effectiveness of the intervention, a sample size of 75 (25 in each locality) will allow for a 60% attrition rate whilst still enabling stratification by BMI and intervention usage frequency. Allowing for such a high attrition rate is prudent given

the evidence of low rates of sustained usages of health apps (Meyerowitz-Katz et al., 2020). We estimate that around 70% of women will opt to include their partner or another buddy in the intervention. Allowing for a similar rate of attrition, this would result in a sample size of 30 partners/buddies. Qualitative interviews will be conducted with a subset of around 18 participants/couples, aiming to provide a diverse range of insights across heavy, medium and light users. Aggregated and anonymous in-app data will be extracted from the Baby Buddy app during selected study periods.

Recruitment

Leaflets promoting Baby Buddy with its new BaSHH feature will be supplied to midwifery trams in the three localities and midwives will be encouraged to alert expectant parents to the feature and to the study. Potential participants will be recruited via Baby Buddy, with in-app push notifications being used to alert participants to the study. A link will take potential participants through to a REDCap page in UCL's Data Safe Haven, where participants will be able to read the participant information leaflet and provide their consent for participation. A screening questionnaire will collect demographic data and participant's height and weight. Initially sampling quotas will not be imposed, although this may be reviewed during the recruitment phase if there is insufficient diversity within the sample. This will be defined as at least 10% non-white British and at least 10% each with obesity and overweight.

Outcome measures

Feasibility and acceptability will be measured both quantitatively and qualitatively and include breadth and depth of engagement with the intervention, user experience, ease of recruiting to the study, study attrition rates and in-app survey completion rates.

Engagement with the intervention will be measured by in-app data which will be extracted post-intervention completion. This will capture frequency, duration and depth of usage of the content in general and specific features such as goal setting and self-monitoring functions. It will also assess partner/buddy involvement in the intervention, reporting the proportion of partners linked into the intervention, their frequency of viewing the weekly messages and frequency of women sharing additional content with

their partner/buddy. In-app data will also be used to determine intervention reach (percentage of Baby Buddy users using BaSHH) and provide insight into the demographic and ethnic profile of users, non-users and lapsed users.

User experience will be measured using the uMARS questionnaire (see *Appendix i*) and supplemented with qualitative telephone/video interviews with around 18 participants or participant couples. These interviews will also include those participants who stop using the intervention, defined by no longer viewing messages or using features. uMARS is a 26-item questionnaire divided into 6 sections. For this study, two questions about future use and paying for the feature will be excluded. The first 3 sections of the uMARS questionnaire will be sent to participants at week 16 of the 32-week programme. These sections focus on engagement, aesthetics and functionality. Early assessment on these three scales is considered important to identify any necessary functionality issues that could be easily amended for the remainder of the study period. The final 3 sections, which focus on information, subjective quality and perceived impact, will be sent out at week 38 when participants have had the opportunity to experience the whole programme. Qualitative interviews will dive deeper into user experience of BaSHH and of the timing, experience and participant-burden of the study questionnaires . These will take place mid-way through the study and at follow-up.

Feasibility of conducting a pilot RCT will be measured by ease of recruiting and attrition rates. Attrition will be defined as no longer viewing any intervention app pages from any time point during the study to follow-up at 38 weeks. Feasibility of measurement tools will be assessed by completion rates, time taken to fill in questionnaires and incomplete data returns as well as in qualitative interviews.

Preliminary feedback on intervention effectiveness will be measured by changes in self-reported dietary and physical activity behaviours and GWG.

Dietary behaviours will be measured using a questionnaire developed specifically for this project, since no existing, validated questionnaire was deemed suitable. The questionnaire (see *Appendix ii*) was developed with support from Dr Rana Conway, a registered Public Health Nutritionist at UCL and is based on other validated dietary

questionnaires, including a two-item questionnaire measuring fruit and vegetable intake (Cappuccio et al., 2003), the short-form Food Frequency Questionnaire (FFQ) (Cleghorn et al., 2016) and the READI questionnaire (Olstad et al., 2017). The questionnaire explores frequency of consumption of key healthy and unhealthy foods and drinks capturing important aspects of diet quality. A measure will be taken at baseline, based on participants' behaviours in the month prior to pregnancy. A follow-up measure will be taken at week 36, based on participants' behaviours in the previous month.

Physical activity will be measured at baseline and follow-up using the Pregnancy Physical Activity Questionnaire (PPAQ) (Chasan-taber et al., 2004) (see *Appendix iii*). An additional question at the start of the PPAQ will identify participants who, for medical reasons, have had to limit their activity. Given that physical activity levels typically decrease in later pregnancy (Currie et al., 2013), the follow-up measure of physical activity will take place at 26 weeks' gestation rather than at the end of the intervention.

Partners living in the same home as the pregnant participant will be asked to complete the dietary behaviours questionnaire, but not the physical activity questionnaire, given the concordance of dietary but not physical activity behaviours in couples (Rhodes et al., 2021).

Table 1 summarises the schedule of proposed outcome measures.

Table 1 Schedule of outcome measures.

Outcomes	**Time 1** Baseline	**Time 2** 16 weeks' gestation	**Time 3** 26 weeks' gestation	**Time 4** 36 weeks' gestation	**Time 5** 38 weeks' gestation
Acceptability		uMARS - A,B&C	Qualitative interviews		uMARS - D,E&F Qualitative interviews
Feasibility	Midwife interviews →				Study attrition rates
Engagement	←		In-app data	→	
Dietary behaviour	Dietary Questionnaire (+partners)			Dietary Questionnaire (+partners)	
Physical activity	PPAQ		PPAQ		

Incentives

Participants will be offered a small incentive of a £15 shopping voucher for completion of the in-app surveys at baseline, and a further £25 voucher at follow-up for completion of all the other in-app surveys. Participants will receive an additional £5 if partners complete the dietary questionnaire. Those participating in qualitative interviews will be offered an additional £20 shopping voucher.

Analysis

Qualitative interviews will be audio recorded, with participants' permission, and transcribed. Data will be analysed thematically.

For quantitative data, categorical variables will be reported as numbers and percentages and continuous variables as mean and standard deviation.

Based on attrition rates seen in other interventions targeting dietary and physical activity behaviours in pregnancy, an attrition rate of <40% will be deemed acceptable (Rhodes et al., 2020).

Paired t-tests will be used to detect changes in dietary and activity behaviours over the course of the intervention. Effect sizes will be measured using Cohen's d. Data will be analysed on an 'intention to treat' basis. All quantitative analysis will be completed on SPSS statistical software (version 23, IBM United Kingdom Limited, Portsmouth, UK; 2015). If feasible secondary analyses will be conducted to explore differences in engagement, acceptability and effectiveness according to variables such as ethnicity, age and degree of food insecurity.

Research governance, ethics and reporting

Ethical approval for the study will be obtained from the UCL Research Ethics Committee (UCL REC). Approval for the study will also be secured from Surrey Heartlands CCG, North East London NHS and Leeds City Council.

The findings of the study will be reported to Surrey Heartlands CCG, North East London NHS, Leeds City Council and Best Beginnings' management team. In addition, a lay summary of the research will be made available to Baby Buddy users via the Best Beginnings' website and participants will be sent a direct link to this summary. Upon completion, the study will be written up and submitted to an open-access academic journal.

The study will be written up and submitted to an open-access academic journal for broader exposure, and results published in peer-reviewed academic journals.

Appendices

Appendix i

Mobile Application Rating Scale: user version (uMARS) (Stoyanov, Hides, Kavanagh, & Wilson, 2016)

NB In this questionnaire 'app' will be replaced with 'Baby Steps to Healthier Habits. In addition, in Section F health behaviours will be replaced by 'what I eat in pregnancy' and 'how active I am in pregnancy'.

Circle the number that most accurately represents the quality of the app you are rating. All items are rated on a 5-point scale from "1.Inadequate" to "5.Excellent". Select N/A if the app component is irrelevant.

App Quality Ratings

SECTION A

Engagement – fun, interesting, customisable, interactive, has prompts (e.g. sends alerts, messages, reminders, feedback, enables sharing)

1. Entertainment: Is the app fun/entertaining to use? Does it have components that make it more fun than other similar apps?

    1. 1 Dull, not fun or entertaining at all

    2. 2 Mostly boring

    3. 3 OK, fun enough to entertain user for a brief time (< 5 minutes)

    4. 4 Moderately fun and entertaining, would entertain user for some time (5-10 minutes total)

    5. 5 Highly entertaining and fun, would stimulate repeat use

2. Interest: Is the app interesting to use? Does it present its information in an interesting way compared to other similar apps?

    1. 1 Not interesting at all

    2. 2 Mostly uninteresting

    3. 3 OK, neither interesting nor uninteresting; would engage user for a brief time (< 5 minutes)

    4. 4 Moderately interesting; would engage user for some time (5-10 minutes total)

    5. 5 Very interesting, would engage user in repeat use

3. Customisation: Does it allow you to customise the settings and preferences that you would like to (e.g. sound, content and notifications)?

    1. 1 Does not allow any customisation or requires setting to be input every time

    2. 2 Allows little customisation and that limits app's functions

    3. 3 Basic customisation to function adequately

    4. 4 Allows numerous options for customisation

    5. 5 Allows complete tailoring the user's characteristics/preferences, remembers all settings

4. Interactivity: Does it allow user input, provide feedback, contain prompts (reminders, sharing options, notifications, etc.)?

    1. 1 No interactive features and/or no response to user input

2. 2 Some, but not enough interactive features which limits app's functions

3. 3 Basic interactive features to function adequately

4. 4 Offers a variety of interactive features, feedback and user input options

5. 5 Very high level of responsiveness through interactive features, feedback and user input options

5. Target group: Is the app content (visuals, language, design) appropriate for the target audience?

1. 1 Completely inappropriate, unclear or confusing

2. 2 Mostly inappropriate, unclear or confusing

3. 3 Acceptable but not specifically designed for the target audience. May be inappropriate/

unclear/confusing at times

4. 4 Designed for the target audience, with minor issues

5. 5 Designed specifically for the target audience, no issues found

SECTION B

Functionality – app functioning, easy to learn, navigation, flow logic, and gestural design of app

6. Performance: How accurately/fast do the app features (functions) and components (buttons/menus) work?

1. 1 App is broken; no/insufficient/inaccurate response (e.g. crashes/bugs/broken features, etc.)

2. 2 Some functions work, but lagging or contains major technical problems

3. 3 App works overall. Some technical problems need fixing, or is slow at times

4. 4 Mostly functional with minor/negligible problems

5. 5 Perfect/timely response; no technical bugs found, or contains a ‘loading time left’ indicator (if relevant)

7. Ease of use: How easy is it to learn how to use the app; how clear are the menu labels, icons and instructions?

    1. 1 No/limited instructions; menu labels, icons are confusing; complicated

    2. 2 Takes a lot of time or effort

    3. 3 Takes some time or effort

    4. 4 Easy to learn (or has clear instructions)

    5. 5 Able to use app immediately; intuitive; simple (no instructions needed)

8. Navigation: Does moving between screens make sense; Does app have all necessary links between screens?

    1. 1 No logical connection between screens at all /navigation is difficult

    2. 2 Understandable after a lot of time/effort

    3. 3 Understandable after some time/effort

4. 4 Easy to understand/navigate

5. 5 Perfectly logical, easy, clear and intuitive screen flow throughout, and/or has shortcuts

9. Gestural design: Do taps/swipes/pinches/scrolls make sense? Are they consistent across all components/screens?

    1. 1 Completely inconsistent/confusing

    2. 2 Often inconsistent/confusing

    3. 3 OK with some inconsistencies/confusing elements

    4. 4 Mostly consistent/intuitive with negligible problems

    5. 5 Perfectly consistent and intuitive

SECTION C

Aesthetics – graphic design, overall visual appeal, colour scheme, and stylistic consistency

10. Layout: Is arrangement and size of buttons, icons, menus and content on the screen appropriate?

    1. 1 Very bad design, cluttered, some options impossible to select, locate, see or read

    2. 2 Bad design, random, unclear, some options difficult to select/locate/see/read

    3. 3 Satisfactory, few problems with selecting/locating/seeing/reading items

4. 4 Mostly clear, able to select/locate/see/read items

5. 5 Professional, simple, clear, orderly, logically organised

11. Graphics: How high is the quality/resolution of graphics used for buttons, icons, menus and content?

    1. 1 Graphics appear amateur, very poor visual design - disproportionate, stylistically inconsistent

    2. 2 Low quality/low resolution graphics; low quality visual design – disproportionate

    3. 3 Moderate quality graphics and visual design (generally consistent in style)

    4. 4 High quality/resolution graphics and visual design – mostly proportionate, consistent in style

    5. 5 Very high quality/resolution graphics and visual design - proportionate, consistent in style throughout

12. Visual appeal: How good does the app look?

    1. 1 Ugly, unpleasant to look at, poorly designed, clashing, mismatched colours

    2. 2 Bad – poorly designed, bad use of colour, visually boring

    3. 3 OK – average, neither pleasant, nor unpleasant

    4. 4 Pleasant – seamless graphics – consistent and professionally designed

5. 5 Beautiful – very attractive, memorable, stands out; use of colour enhances app features/menus

SECTION D

Information – Contains high quality information (e.g. text, feedback, measures, references) from a credible source

13. Quality of information: Is app content correct, well written, and relevant to the goal/topic of the app?

N/A There is no information within the app

1. 1 Irrelevant/inappropriate/incoherent/incorrect
2. 2 Poor. Barely relevant/appropriate/coherent/may be incorrect
3. 3 Moderately relevant/appropriate/coherent/and appears correct
4. 4 Relevant/appropriate/coherent/correct
5. 5 Highly relevant, appropriate, coherent, and correct

14. Quantity of information: Is the information within the app comprehensive but concise?

N/A There is no information within the app

1. 1 Minimal or overwhelming
2. 2 Insufficient or possibly overwhelming
3. 3 OK but not comprehensive or concise

4. 4 Offers a broad range of information, has some gaps or unnecessary detail; or has no links to more information and resources

5. 5 Comprehensive and concise; contains links to more information and resources

15. Visual information: Is visual explanation of concepts – through charts/graphs/images/videos, etc. – clear, logical, correct?

N/A There is no visual information within the app (e.g. it only contains audio, or text)

1. 1 Completely unclear/confusing/wrong or necessary but missing

2. 2 Mostly unclear/confusing/wrong

3. 3 OK but often unclear/confusing/wrong

4. 4 Mostly clear/logical/correct with negligible issues

5. 5 Perfectly clear/logical/correct

16. Credibility of source: does the information within the app seem to come from a credible source?

N/A There is no information within the app

1. 1 Suspicious source

2. 2 Lacks credibility

3. 3 Not suspicious but legitimacy of source is unclear

4. 4 Possibly comes from a legitimate source

5. 5 Definitely comes from a legitimate/specialised source

SECTION E

App subjective quality

17. Would you recommend this app to people who might benefit from it?

1Not at all I would not recommend this app to anyone

2 There are very few people I would recommend this app to
3 Maybe There are several people I would recommend this app to
4 There are many people I would recommend this app to

5 Definitely I would recommend this app to everyone

18. What is your overall (star)rating of the app?

1 □ One of the worst apps I've used
2 □□
3 □□□ Average
4 □□□□

5 □□□□□ One of the best apps I've used

SECTION F

Perceived impact

1. Awareness – This app has increased my awareness of the importance of addressing my health behaviours

Strongly disagree Strongly Agree 12345

2. Knowledge – This app has increased my knowledge/understanding of my health behaviour

Strongly disagree Strongly Agree 12345

3. Attitudes – The app has changed my attitudes toward improving my health behaviour

Strongly disagree Strongly Agree 12345

4. Intention to change – The app has increased my intentions/motivation to address this health behaviour

Strongly disagree Strongly Agree 12345

5. Help seeking – This app would encourage me to seek further help to address the health behaviour (if I needed it)

Strongly disagree Strongly Agree 12345

6. Behaviour change – Use of this app will increase/decrease the health behaviour

Strongly disagree Strongly Agree 12345

Further comments about the app?

Thank you.

Appendix ii

Amalgamated food frequency questionnaire

Baseline: The following questions ask you about what you normally eat. Please think back and base your answers on what you ate in the month before you were pregnant.

Follow-up: The following questions ask you about what you normally eat. Please base your answers on what you ate in the last month.

1. In the month before you were pregnant, how many portions of vegetables (**excluding** potatoes, cassava or plantains) did you usually eat? Include vegetables eaten at mealtimes or as a snack. Examples of a portion are 2 heaped tablespoons of broccoli or carrots, 3 tablespoons of sweetcorn or peas or a bowl of salad.

Less than 1 per week	0
1-2 per week	1.5/7
3-6 per week	4.5/7
1 -2 per day	1.5
3-4 per day	3.5
5 or more per day	5

2. In the month before you were pregnant, how many portions of fruit did you usually eat? Include fruit eaten at mealtimes or as a snack. Examples of portion are 1 apple or banana, a large slice of melon, 2 plums or satsumas, a small bowl of grapes, 2 tablespoons of tinned fruit or ½ tablespoon of dried fruit.

Less than 1 per week	0
1-2 per week	1.5/7
3-6 per week	4.5/7
1 -2 per day	1.5
3-4 per day	3.5
5 or more per day	5

3. Thinking about the bread including rolls, chapatis, naan, wraps, pitta etc, you ate in the month before you were pregnant, which of the following applies to you:

I don’t eat bread etc	0
I ate only white bread etc	1

I ate mainly white bread etc	2
I ate a mix of white and brown/wholemeal bread etc	3
I ate mainly brown/wholemeal bread etc	4
I ate only brown/wholemeal bread etc	5

4. And thinking about the rice and/or pasta and/or noodles and/or couscous you ate in the month before you were pregnant, which of the following applies to you:

I don’t eat rice, pasta etc	0
I ate only white rice, regular pasta etc	1
I ate mainly white rice, regular pasta etc	2
I ate a mix of white and brown/wholemeal rice, pasta etc	3
I ate mainly brown/wholemeal rice, pasta etc	4
I ate only brown/wholemeal rice, pasta etc	5

5. In the month before you were pregnant, how many days a week did you eat or drink the following?

(Drop down)

Crisps, salted nuts or other savoury snacks	0	1	2	3	4	5	6	7
Chocolates or sweets	0	1	2	3	4	5	6	7
Ice cream or ice lollies	0	1	2	3	4	5	6	7
Biscuits	0	1	2	3	4	5	6	7
Cakes, sweet pastries or donuts	0	1	2	3	4	5	6	7
Savoury pies, pasties and sausage rolls	0	1	2	3	4	5	6	7
Unsalted nuts or seeds	0	1	2	3	4	5	6	7
Fruit juice or smoothies (not cordial or squash)	0	1	2	3	4	5	6	7
Chips/French fries/fried potatoes	0	1	2	3	4	5	6	7

Takeaway or ready meals including burgers, fried chicken, breaded chicken/nuggets breaded or battered fish, pizza, pasta, curries, noodles, other Thai, Chinese and Indian dishes	0	1	2	3	4	5	6	7
Red meat - beef, lamb or pork as chops, steaks, roasts, mince, stir fries, stews, curries etc	0	1	2	3	4	5	6	7
Processed meat or meat products (e.g. sausages, bacon, salami, frankfurters)	0	1	2	3	4	5	6	7
Oily fish – like herrings, sardines, salmon, trout, mackerel	0	1	2	3	4	5	6	7

Beans and pulses (e.g. baked beans, lentils, dahl, chickpeas, houmous)	0	1	2	3	4	5	6	7

6. Thinking about the soft drinks, including fizzy drinks, sports drinks, cordials, squash (but NOT fruit juice, smoothies or water) you drank in the last month before you were pregnant, which applies to you:

I didn't drink soft drinks	0
I drank only regular drinks rather than diet or sugar free drinks	1
I drank mainly regular drinks rather than diet or sugar free drinks	2
I drank a mix of regular drinks and diet or sugar free drinks	3
I drank mainly diet or sugar free drinks	4
I drank only diet or sugar free drinks	5

7. In the month before you were pregnant, how much water did you usually drink? (one glass = 250 ml)

Glasses per day

0 1 2 3 4 5 6 7 8+

8. In the 3 months before you were pregnant, how many rounded teaspoons of sugar, honey, or syrup did you usually have in a day (e.g. in tea, coffee, milk or on bread, cereal, fruit)?

Teaspoons per day

0 1 2 3 4 5 6 7 8 9 10+

Baseline questions only:

Which of the following statements best describes you?

I am vegetarian

I am vegan

I am pescatarian (I eat fish, but not meat)

I am flexitarian (I eat meat infrequently)

I eat meat regularly

Appendix iii

Pregnancy Physical Activity Questionnaire (Chasan-taber et al., 2004)

9364

Office Use Only - ID# ☐☐☐☐

UMASS.

Pregnancy Physical Activity Questionnaire

Instructions:
Please use an ordinary No. 2 pencil. *Fill in the circles completely. The Question will be read by a machine so if you need to change your answer, erase the incorrect mark* ***completely****. If you have comments, please write them on the back of the questionnaire.*

Example: During this trimester, when you are NOT at work, how much time do you usually spend:

E1. **Taking care of an older adult**

If you take care of your mom for 2 hours each day, then your answer should look like this... →

- ○ None
- ○ Less than 1/2 hour per day
- ○ 1/2 to almost 1 hour per day
- ○ 1 to almost 2 hours per day
- ● 2 to almost 3 hours per day
- ○ 3 or more hours per day

It is very important you tell us about yourself honestly. There are no right or wrong answers. We just want to know about the things you are doing during this trimester.

1. Today's Date: ☐☐ / ☐☐ / ☐☐☐☐ (Month / Day / Year)
2. What was the first day of your last period? ☐☐ / ☐☐ / ☐☐☐☐ (Month / Day / Year) ○ I don't know
3. When is your baby due? ☐☐ / ☐☐ / ☐☐☐☐ (Month / Day / Year) ○ I don't know

During this trimester, when you are NOT at work, how much time do you usually spend:

4. **Preparing meals (cook, set table, wash dishes)**
   - ○ None
   - ○ Less than 1/2 hour per day
   - ○ 1/2 to almost 1 hour per day
   - ○ 1 to almost 2 hours per day
   - ○ 2 to almost 3 hours per day
   - ○ 3 or more hours per day
5. **Dressing, bathing, feeding children while you are sitting**
   - ○ None
   - ○ Less than 1/2 hour per day
   - ○ 1/2 to almost 1 hour per day
   - ○ 1 to almost 2 hours per day
   - ○ 2 to almost 3 hours per day
   - ○ 3 or more hours per day

Page 1

9364

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During this trimester, when you are NOT at work, how much time do you usually spend:

6. **Dressing, bathing, feeding children while you are standing**
   - O None
   - O Less than 1/2 hour per day
   - O 1/2 to almost 1 hour per day
   - O 1 to almost 2 hours per day
   - O 2 to almost 3 hours per day
   - O 3 or more hours per day

7. **Playing with children while you are sitting or standing**
   - O None
   - O Less than 1/2 hour per day
   - O 1/2 to almost 1 hour per day
   - O 1 to almost 2 hours per day
   - O 2 to almost 3 hours per day
   - O 3 or more hours per day

8. **Playing with children while you are walking or running**
   - O None
   - O Less than 1/2 hour per day
   - O 1/2 to almost 1 hour per day
   - O 1 to almost 2 hours per day
   - O 2 to almost 3 hours per day
   - O 3 or more hours per day

9. **Carrying children**
   - O None
   - O Less than 1/2 hour per day
   - O 1/2 to almost 1 hour per day
   - O 1 to almost 2 hours per day
   - O 2 to almost 3 hours per day
   - O 3 or more hours per day

10. **Taking care of an older adult**
    - O None
    - O Less than 1/2 hour per day
    - O 1/2 to almost 1 hour per day
    - O 1 to almost 2 hours per day
    - O 2 to almost 3 hours per day
    - O 3 or more hours per day

11. **Sitting and using a computer or writing, while not at work**
    - O None
    - O Less than 1/2 hour per day
    - O 1/2 to almost 1 hour per day
    - O 1 to almost 2 hours per day
    - O 2 to almost 3 hours per day
    - O 3 or more hours per day

12. **Watching TV or a video**
    - O None
    - O Less than 1/2 hour per day
    - O 1/2 to almost 2 hours per day
    - O 2 to almost 4 hours per day
    - O 4 to almost 6 hours per day
    - O 6 or more hours per day

13. **Sitting and reading, talking, or on the phone, while not at work**
    - O None
    - O Less than 1/2 hour per day
    - O 1/2 to almost 2 hours per day
    - O 2 to almost 4 hours per day
    - O 4 to almost 6 hours per day
    - O 6 or more hours per day

14. **Playing with pets**
    - O None
    - O Less than 1/2 hour per day
    - O 1/2 to almost 1 hour per day
    - O 1 to almost 2 hours per day
    - O 2 to almost 3 hours per day
    - O 3 or more hours per day

15. **Light cleaning (make beds, laundry, iron, put things away)**
    - O None
    - O Less than 1/2 hour per day
    - O 1/2 to almost 1 hour per day
    - O 1 to almost 2 hours per day
    - O 2 to almost 3 hours per day
    - O 3 or more hours per day

16. **Shopping (for food, clothes, or other items)**
    - O None
    - O Less than 1/2 hour per day
    - O 1/2 to almost 1 hour per day
    - O 1 to almost 2 hours per day
    - O 2 to almost 3 hours per day
    - O 3 or more hours per day

9364

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During this trimester, when you are NOT at work, how much time do you usually spend:

17. **Heavier cleaning (vacuum, mop, sweep, wash windows)**

- O None
- O Less than 1/2 hour per week
- O 1/2 to almost 1 hour per week
- O 1 to almost 2 hours per week
- O 2 to almost 3 hours per week
- O 3 or more hours per week

18. **Mowing lawn while on a riding mower**

- O None
- O Less than 1/2 hour per week
- O 1/2 to almost 1 hour per week
- O 1 to almost 2 hours per week
- O 2 to almost 3 hours per week
- O 3 or more hours per week

19. **Mowing lawn using a walking mower, raking, gardening**

- O None
- O Less than 1/2 hour per week
- O 1/2 to almost 1 hour per week
- O 1 to almost 2 hours per week
- O 2 to almost 3 hours per week
- O 3 or more hours per week

Going Places...

During this trimester, how much time do you usually spend:

20. **Walking slowly to go places (such as to the bus, work, visiting)** ***Not for fun or exercise***

- O None
- O Less than 1/2 hour per day
- O 1/2 to almost 1 hour per day
- O 1 to almost 2 hours per day
- O 2 to almost 3 hours per day
- O 3 or more hours per day

21. **Walking quickly to go places (such as to the bus, work, or school)** ***Not for fun or exercise***

- O None
- O Less than 1/2 hour per day
- O 1/2 to almost 1 hour per day
- O 1 to almost 2 hours per day
- O 2 to almost 3 hours per day
- O 3 or more hours per day

22. **Driving or riding in a car or bus**

- O None
- O Less than 1/2 hour per day
- O 1/2 to almost 1 hour per day
- O 1 to almost 2 hours per day
- O 2 to almost 3 hours per day
- O 3 or more hours per day

For Fun or Exercise...

During this trimester, how much time do you usually spend:

23. **Walking slowly for fun or exercise**

- O None
- O Less than 1/2 hour per week
- O 1/2 to almost 1 hour per week
- O 1 to almost 2 hours per week
- O 2 to almost 3 hours per week
- O 3 or more hours per week

24. **Walking more quickly for fun or exercise**

- O None
- O Less than 1/2 hour per week
- O 1/2 to almost 1 hour per week
- O 1 to almost 2 hours per week
- O 2 to almost 3 hours per week
- O 3 or more hours per week

25. **Walking quickly up hills for fun or exercise**

- O None
- O Less than 1/2 hour per week
- O 1/2 to almost 1 hour per week
- O 1 to almost 2 hours per week
- O 2 to almost 3 hours per week
- O 3 or more hours per week

9364

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During this trimester, how much time do you usually spend:

26. **Jogging**
- O None
- O Less than 1/2 hour per week
- O 1/2 to almost 1 hour per week
- O 1 to almost 2 hours per week
- O 2 to almost 3 hours per week
- O 3 or more hours per week

27. **Prenatal exercise class**
- O None
- O Less than 1/2 hour per week
- O 1/2 to almost 1 hour per week
- O 1 to almost 2 hours per week
- O 2 to almost 3 hours per week
- O 3 or more hours per week

28. **Swimming**
- O None
- O Less than 1/2 hour per week
- O 1/2 to almost 1 hour per week
- O 1 to almost 2 hours per week
- O 2 to almost 3 hours per week
- O 3 or more hours per week

29. **Dancing**
- O None
- O Less than 1/2 hour per week
- O 1/2 to almost 1 hour per week
- O 1 to almost 2 hours per week
- O 2 to almost 3 hours per week
- O 3 or more hours per week

Doing other things for fun or exercise? Please tell us what they are.

30. _____ Name of Activity
- O None
- O Less than 1/2 hour per week
- O 1/2 to almost 1 hour per week
- O 1 to almost 2 hours per week
- O 2 to almost 3 hours per week
- O 3 or more hours per week

31. _____ Name of Activity
- O None
- O Less than 1/2 hour per week
- O 1/2 to almost 1 hour per week
- O 1 to almost 2 hours per week
- O 2 to almost 3 hours per week
- O 3 or more hours per week

Please fill out the next section if you work for wages, as a volunteer, or if you are a student. If you are a homemaker, out of work, or unable to work, you do not need to complete this last section.

At Work...

During this trimester, how much time do you usually spend:

32. **Sitting at working or in class**

- O None
- O Less than 1/2 hours per day
- O 1/2 to almost 2 hours per day
- O 2 to almost 4 hours per day
- O 4 to almost 6 hours per day
- O 6 or more hours per day

33. **Standing or slowly walking at work while carrying things (heavier than a 1 gallon milk jug)**
- O None
- O Less than 1/2 hour per day
- O 1/2 to almost 2 hours per day
- O 2 to almost 4 hours per day
- O 4 to almost 6 hours per day
- O 6 or more hours per day

34. **Standing or <u>slowly</u> walking at work <u>not</u> carrying anything**
- O None
- O Less than 1/2 hours per day
- O 1/2 to almost 2 hours per day
- O 2 to almost 4 hours per day
- O 4 to almost 6 hours per day
- O 6 or more hours per day

35. **Walking <u>quickly</u> at work while <u>carrying</u> things (heavier than a 1 gallon milk jug)**
- O None
- O Less than 1/2 hour per day
- O 1/2 to almost 2 hours per day
- O 2 to almost 4 hours per day
- O 4 to almost 6 hours per day
- O 6 or more hours per day

36. **Walking <u>quickly</u> at work <u>not</u> carrying anything**
- O None
- O Less than 1/2 hour per day
- O 1/2 to almost 2 hours per day
- O 2 to almost 4 hours per day
- O 4 to almost 6 hours per day
- O 6 or more hours per day

Thank You