THE INFLUENCE OF INTERVENTION CO-DESIGN STRATEGIES ON WEIGHT MANAGEMENT AND HEALTH IN OVERWEIGHT AND OBESE POSTPARTUM WOMEN

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ABSTRACT

Postpartum women experience an array of barriers to physical activity and healthy eating during and following pregnancy. These barriers undoubtedly influence women's ability to engage in a healthy postpartum lifestyle. It is not known, however, if (i) overweight and obese women experience the same barriers to physical activity and diet as normal weight women and (ii) if involving women in the co-design of lifestyle interventions encourages successful outcomes. Therefore, the aim of this thesis was to understand the perceived barriers to healthy eating and physical activity during and following pregnancy, with the aim of co-creating a lifestyle intervention with postpartum women to minimise these perceived barriers and encourage weight management and health in overweight and obese women following childbirth. Chapter 3 highlights that, through the use of semi-structured interviews, overweight and obese women experience many barriers when attempting to engage in physical activity and eat healthily during and following pregnancy. The delivery of Patient and Public Involvement work in Chapter 4 allowed postpartum women to provide their thoughts and opinions on the design and delivery of a dietary and physical activity intervention, whilst considering the barriers highlighted by women in Chapter 3. Chapter 5 demonstrated that co-designed dietary and physical activity interventions were effective in encouraging postpartum weight loss, improvements in physical activity and eating behaviours in overweight and obese women. Women in the diet and exercise groups experienced a 5.83 ± 3.41kg (7.54 ± 4.84%) and 3.98 ± 2.98kg (5.17 ± 3.76%) weight loss, from baseline to follow-up. This study was the first to offer postpartum women the choice of engaging in a diet or physical activity intervention and demonstrated the importance of involving women in the co-design of lifestyle programs in encouraging successful post-intervention outcomes. In behaviour change settings, postpartum women should be provided with individualised support and autonomy over lifestyle choices and given the opportunity to offer their inputs into the delivery of lifestyle support programs following childbirth.

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LIST OF ABBREVIATIONS

BMI- Body Mass Index

GWG- Gestational Weight Gain

IOM- Institute of Medicine

LGA- Large for Gestational Age

OR- Odds Ratio

ARD- Absolute Risk Difference

GDM- Gestational Diabetes Mellitus

QoL- Quality of Life

PPWR- Postpartum Weight Retention

FFM- Fat-Free Mass

NICE- National Institute of Health and Care Excellence

PPI- Patient and Public Involvement

CENTRAL- Central Register of Controlled Trials

RCTs- Randomised Controlled Trials

CONSORT- Consolidated Standards of Reporting Trials

PPAQ- Pregnancy Physical Activity Questionnaire

DEI- Dietary Energy Intake

DRI- Dietary Reference Intake

EAR- Estimated Average Requirement

RDA- Recommended Daily Allowance

CI- Confidence Interval

GI- Glycaemic Index

NHS- National Health Service

PAIGE- Postnatal Lifestyle Intervention for Overweight Women with Previous Gestational Diabetes

NRES- National Research Ethics Service

DXA- Dual-Energy X-ray Absorptiometry

FM- Fat Mass

A/G- Android/Gynoid

FMI- Fat Mass Index

TC- Total Cholesterol

HDL- High-Density Lipoprotein Cholesterol

LDL- Low-Density Lipoprotein Cholesterol

TG- Triglyceride

HbA1c- Glycated Haemoglobin

BP- Blood Pressure

HR- Heart Rate

SF-36- Short-Form 36

MET- Metabolic Equivalent

TFEQ- Three Factor Eating Questionnaire

PSQI- Pittsburgh Sleep Quality Index

EPDS- Edinburgh Postnatal Depression Scale

FM%- Fat Mass Percentage

LTPA- Leisure-time Physical Activity

UE- Uncontrolled Eating

CR- Cognitive Restraint

EE- Emotional Eating

KAN-DO- Kids and Adults Now – Defeat Obesity

SMS- Short Message Service

GP- General Practitioner

Chapter 1: General Introduction

Since 1975, worldwide obesity prevalence has increased threefold. In 2016, more than 1.9 billion (39%) adults (18 years and older) were overweight and of these, 650 million (13%) were obese (World Health Organisation, 2020a). A high body mass index (BMI) is a major risk factor for non-communicable diseases such as: cardiovascular diseases (primarily stroke and heart disease), which were the leading cause of death in 2012; musculoskeletal disorders; diabetes; and some cancers including breast, ovarian, prostate and kidney (World Health Organisation, 2020a). Women of reproductive age represent a sub-population with one of the highest increases in obesity rates in recent years (NCD Risk Factor Collaboration, 2016). In most developed countries, over half of the women of childbearing age are either overweight (BMI 25-29.9 kg·m^2) or obese (BMI > 30 kg·m^2) (NHS Digital, 2017). Furthermore, in the United Kingdom, around one in five women are obese at the time of antenatal booking (Heslehurst et al., 2007; Heslehurst, Rankin, Wilkinson, & Summerbell, 2010; Kanagalingam, Forouhi, Greer, & Sattar, 2005), with other developed countries showing similar incidences (Goldstein et al., 2017; LaCoursiere, Bloebaum, Duncan, & Varner, 2005).

Although pregnancy requires some additional weight gain, many women experience excessive gestational weight gain (GWG); for example, Johnson et al. (2013) showed that 73% of women, from a sample of 8,293, gained weight in excess of the Institute of Medicine (IOM) guidelines (Institute of Medicine (US) and National Research Council (US) Committee to Reexamine IOM Pregnancy Weight Guidelines, 2009). The IOM guidelines recommend a GWG of 11.3-15.9kg for normal weight women, 6.8-11.3kg for overweight women, and 5 and 9.1kg for obese women in order to encourage healthy maternal and foetal outcomes (Rogozińska et al., 2019). Weight gain above these recommendations can result in an increased risk of negative maternal and offspring outcomes, such as a 50% increase in the risk of caesarean section and a two-fold increase in the risk of large for gestational age (LGA) offspring (Rogozińska et al., 2019). Some suggest that the IOM guidelines are too conservative for overweight and obese women; with suggestions that less GWG, weight maintenance or weight loss is more appropriate for the population (Bodnar, Siega-Riz, Simhan, Himes, & Abrams, 2010; Kiel, Dodson, Artal, Boehmer, & Leet, 2007; Oken, Kleinman, Belfort, Hammitt, & Gillman, 2009). Despite this, little work has been done to develop updated weight management guidelines for overweight and obese pregnant women; an area which requires urgent attention to help stem the inter-generational cycle of obesity.

In comparison to normal weight women, women who are overweight or obese are more likely to experience excessive GWG (Deputy et al. 2015) and weight retention long beyond the postpartum period (Kirkegaard et al., 2015). The postpartum period is often defined as the 12 months after childbirth, during which time the weight gained during pregnancy should be lost, however this prolonged weight retention often results in elevated inter-partum BMI and women entering subsequent pregnancies with higher BMI's (Kirkegaard et al., 2015) (Figure 1.1). Excessive GWG can result in numerous adverse maternal and foetal outcomes, including higher risk of LGA offspring (odds ratio (OR), 1.85 [1.76-1.95]; absolute risk difference (ARD), 4% [2%-5%]), macrosomia (OR, 1.95 [1.79-2.11]; ARD, 6% [4%-9%]) and caesarean section delivery (OR, 1.30 [1.25-1.35]; ARD, 4% [3%-6%]) (Goldstein et al., 2017). Hypertensive disorders, including preeclampsia and gestational hypertension, and gestational diabetes (GDM) are also more common in women who exceed the IOM weight gain guidelines (Ren et al., 2018).

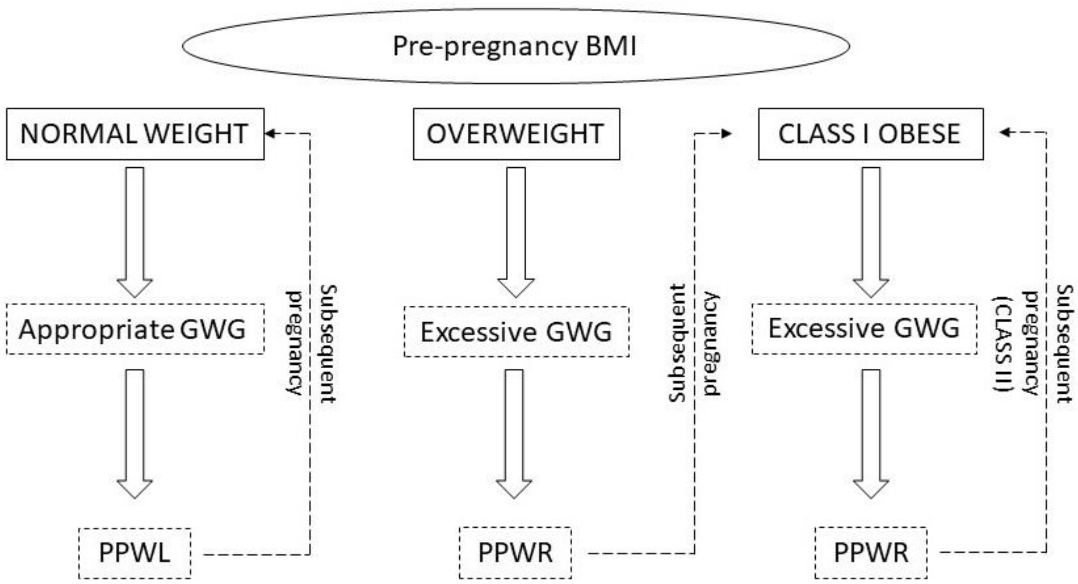

Figure 1.1 Inter-relationships between gestational weight gain, postpartum weight management and BMI in subsequent pregnancies. Abbreviations: GWG, gestational weight gain; PPWL; postpartum weight loss; PPWR, postpartum weight retention.

It is now recognised that the first 1000 days from conception is an important epoch that can have a significant impact on later offspring health (Pietrobelli, Agosto, & MeNu Group, 2017). Even from the earliest moments in life the risk of developing chronic diseases, such as obesity, coronary heart disease and type 2 diabetes, is determined (Fraser et al., 2010). Maternal obesity increases nutrient transfer across the placenta, inducing changes to insulin growth factor and circulating insulin levels, which can result in higher adiposity at birth (Catalano & Shankar, 2017). These alterations in metabolism can impair subsequent appetite regulation through the breakdown of normal regulatory systems (Catalano & Shankar, 2017). Maternal obesity in the first trimester makes it twice as likely that offspring will be obese at 2 years of age, and 2.3 times as likely at both 3 years and 4 years of age (Whitaker, 2004). Meta-analytical data suggest that exceeding the recommended GWG guidelines increases the risk of obesity in offspring by around 30% (Nehring, Lehmann, & von Kries, 2013). Strikingly, percentage body fat at age 30 years is greater in offspring born to mothers who had higher BMI's at their first antenatal visit (rising by 0.35%/kg/m^2; $p<0.001$; Reynolds, Osmond, Phillips, & Godfrey, 2010). Given these associations, it is perhaps not surprising that, like adult obesity, the worldwide prevalence of childhood obesity has increased at an alarming rate from 0.9% to 7.8% in girls and 0.7% to 5.6% in boys between 1975 and 2016 (NCD Risk Factor Collaboration, 2016). These combined findings highlight the importance of encouraging a healthy BMI in women of childbearing age and promoting appropriate GWG and the loss of pregnancy-related weight gain to encourage positive short- and long-term maternal and offspring outcomes.

Despite increasing evidence for the benefits of a healthy lifestyle during and following pregnancy (Aviram, Hod, & Yogev, 2011; Barker et al., 1993; Zhang & Ning, 2011), physical activity levels have been shown to decline during pregnancy (Brown, Heesch, & Miller, 2009; Engberg et al., 2012) and often remain reduced long into the postpartum period (Berge, Larson, Bauer, & Neumark-Sztainer, 2011; Fell, Joseph, Armson, & Dodds, 2009; Gaston & Cramp, 2011; Pereira et al., 2007). Diet quality, referring to the balance between the consumption of healthy (*e.g.* wholegrains, fruits, vegetables) and unhealthy foods (*e.g.* refined sugar, saturated fats), declines during pregnancy, particularly in overweight and obese women, with this lower diet quality persisting following childbirth (Moran, Sui, Cramp, & Dodd, 2013). Perceived quality of life (QoL) also decreases after pregnancy (Martínez-Galiano, Hernández-Martínez, Rodríguez-Almagro, & Delgado-Rodríguez, 2019), which may be associated with these observed reductions in physical activity (Bahadoran, Tirkesh, & Oreizi, 2014) and diet quality.

Recently, Altazan et al. (2019) demonstrated lower physical QoL from early to late pregnancy and decreased mental QoL up to 12 months postpartum in women who experienced GWG in excess of IOM guidelines, highlighting the importance of encouraging appropriate GWG to improve long-term maternal outcomes.

A number of barriers to a healthy lifestyle during and following pregnancy have been identified, including a lack of time (Albright et al., 2015; Coll et al., 2017; Cramp & Bray, 2010), lack of social support (Coll et al., 2017), fatigue (Albright et al., 2015; Cramp & Bray, 2010), lack of knowledge about how to exercise safely (Coll et al., 2017), lack of physical activity advice from healthcare professionals (Coll et al., 2017) and prioritising the child's needs over healthy eating (MacMillan Uribe & Olson, 2018). Of note, physical activity is defined as 'any bodily movement produced by skeletal muscles that require energy expenditure' (World Health Organisation, 2020b), and exercise is defined as 'a subset of physical activity that is planned, structured, and repetitive and has a final or an immediate objective; the improvement or maintenance of physical fitness' (Caspersen, Powell, & Christenson, 1985). Although knowledge of the potential barriers to following a healthy lifestyle during and following pregnancy has expanded in recent years, there remains a dearth of information related to barriers to participation of overweight and obese women and further work is required to understand these women's experiences during and following pregnancy. It may be that overweight and obese pregnant and postpartum women experience unique challenges, which are weight-related, that limit their ability to adopt mainstream lifestyle interventions. Indeed, a number of postpartum lifestyle interventions in overweight and obese populations have proven ineffective in promoting behaviour change (Heppner et al., 2011; Skouteris et al., 2012; Vesco et al., 2012) and significantly reducing BMI (Østbye et al., 2009; Walker et al., 2012). One of the reasons for this may be the lack of formative work carried out prior to implementing lifestyle interventions in overweight and obese postpartum women, with only few recent investigations completing initial formative work (Graham, Uesugi, & Olson, 2016; Olson et al., 2018). A comprehensive understanding of the barriers preventing overweight and obese women from achieving a healthy lifestyle during and following pregnancy is crucial in order to guide the design and delivery of future lifestyle interventions, with the aim of promoting long-term health, appropriate GWG and postpartum weight loss.

Therefore, the aims of this thesis were to:

1) Examine the experiences of overweight and obese women regarding physical activity, diet, and QoL prior to, during, and following pregnancy. (Chapter 3)
2) Examine the thoughts and opinions of normal weight, overweight and obese postpartum women on the design and delivery of lifestyle interventions. (Chapter 4)
3) Examine the effects of a self-selected, technology-supported, lifestyle intervention on weight management and health in overweight and obese postpartum women. (Chapter 5)
4) Assess the Thoughts and Opinions of Postpartum Women Following Engagement in a Lifestyle Intervention: Exit Questionnaires (Chapter 6)

Chapter 2: Literature Review

Note: This literature review is made up of three review papers. Two of the three review papers have been submitted for publication and the third review paper is already published. As such, these sections are presented in their 'journal format', complete with individual reference list, but have been numbered [section headings] in line with this thesis.

2.1 Overview

As highlighted in Chapter 1, women often experience excessive GWG (Johnson et al., 2013) and weight retention long beyond the postpartum period (Kirkegaard et al., 2015). These experiences result in a multitude of adverse maternal and offspring outcomes including: an increased risk of caesarean section delivery, GDM and hypertension; macrosomia; and later life maternal and offspring obesity (Goldstein et al., 2017; Nehring et al., 2013; Ren et al., 2018). Despite evidence for the benefits of a healthy lifestyle, such as a decreased risk of (i) pre-eclampsia, (ii) congenital abnormalities and (iii) pre-term labour (Clapp, 2000; Martin & Brunner Huber, 2010; Mudd et al., 2013), physical activity levels tend to decline and diet quality worsens in the antenatal period (Engberg et al., 2012; Gaston & Cramp, 2011; Moran et al., 2013). In the years following childbirth, and beyond, physical activity levels often remain reduced and women continue to consume an unhealthy diet (Brown et al., 2009; Berge et al., 2011). Therefore, there is a need for interventions aimed at supporting the maintenance or improvement of physical activity levels and diet quality during and following pregnancy, leading to improvements in maternal and offspring health and more specifically maternal weight management. The purpose of this literature review was to (i) explore the effects of excessive GWG and postpartum weight retention (PPWR) on maternal and offspring health outcomes in multiparous women, and (ii) examine current antenatal and postnatal lifestyle support strategies.

The first review paper examined the effects of positive energy balance, resultant excessive GWG and PPWR, on maternal and child health during pregnancy, in the inter-pregnancy period, and in subsequent pregnancies in multiparous women. The review: (i) provided information on the determinants of excessive GWG; (ii) examined the effects of obesity on maternal and offspring health in initial and subsequent pregnancies; and (iii) provided an insight into the translation of nutritional and weight management interventions into antenatal care, especially for mothers with obesity.

In the second review paper the relationship between exercise and antenatal and postnatal weight management was investigated. In 2017, 21.6% of women were obese at the time of antenatal booking (Public Health England, 2019), which represents a 6% increase from data collected 10 years earlier (N Heslehurst et al., 2010). Therefore, it was crucial to provide an updated review of studies conducted in the last decade, in order to understand any advances made in the design and delivery of, and outcomes from, exercise interventions in pregnancy and postpartum populations.

The third review was conducted in order to develop up-to-date, antenatal, dietary energy intake guidelines, with a particular focus on (i) macro and micronutrient needs, (ii) supplementation requirements and (iii) dietary interventions for gestational weight management. Guidance on the required dietary energy intake according to pre-gravid BMI was published in 2004 by Butte et al., although it was considered important to develop updated recommendations in order to improve our understanding of appropriate nutritional support to encourage a healthy pregnancy (*i.e.*, appropriate GWG based on pre-pregnancy BMI) and successful dietary intervention outcomes (*i.e.*, a higher proportion of women with appropriate GWG in intervention vs. control groups).

2.2 Excessive Gestational Weight Gain and Postpartum Weight Retention: Impact on Maternal and Foetal Health during Pregnancy and Subsequent Pregnancies

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2.2.1 Abstract

In order to support a healthy pregnancy, extra energy is required, although some guidelines are modest and advise an extra 200 kcal·day^{-1} in the third trimester only. GWG should be limited and based upon pre-pregnancy BMI, although in many cases pregnancy results in excessive GWG. Following childbirth, many women do not lose the weight gained during pregnancy, especially when the weight gained was in excess of the recommended guidelines, and this prolonged PPWR can result in the development of overweight and obesity. In women with sustained (>1 y) PPWR, weight gain is often compounded over subsequent pregnancies and can lead to greater degrees of overweightness and obesity. Obese pregnant women and their offspring are at an increased risk of numerous unfavourable health outcomes. The aim of this review was to describe the effects of dietary energy intake, resulting in excessive GWG and PPWR, on maternal and child health during pregnancy and in subsequent pregnancies in multiparous women. Consideration was also given to how nutritional interventions could be implemented into obstetric practice.

Keywords: maternal energy intake, inter-pregnancy, gestational weight gain, postpartum weight retention, maternal health, child health

2.2.2 Introduction

To encourage healthy foetal growth and development during pregnancy, additional maternal energy intake is required for those women that begin pregnancy underweight (BMI <18.5 kg·m^2), normal weight (BMI 18.5-24.9 kg·m^2) or over-weight (BMI 25-29.9 kg·m^2; Kominiarek & Rajan, 2016). To achieve healthy GWG, it has recently been suggested that obese (BMI >30 kg·m^2) women do not require additional energy during pregnancy (Most et al., 2019). To achieve the recommended 0.5-2.0 kg weight gain in the first trimester, the IOM and American College of Obstetricians and Gynaecologists recommend that women maintain pre-pregnancy energy intake as the energy cost of weight gain is considered minimal (Institute of Medicine and National Research Council of the National Academies, 2009; American College of Obstetricians and Gynecologists, 2016).

Previously, the energy intake requirement model by Thomas et al (2012) suggested an additional 100-200 kcal·day^{-1} in the first trimester (Thomas et al., 2012), although this assumes that physical activity remains similar to pre-pregnancy levels (Thomas et al., 2012; Butte, Wong, Treuth, Ellis & O'Brian Smith, 2004). During the second and third trimesters, the IOM recommend an additional 340 kcal·day^{-1} and 452 kcal·$^{-1}$day (Institute of Medicine and National Research Council of the National Academies, 2009). These recommendations fail to account for BMI-specific weight gain guidelines. According to the energy intake requirements model, underweight and normal weight women require an additional energy intake of 400-600 kcal·day^{-1}, whilst overweight and obese women require an additional 220-350 kcal·day^{-1} (Thomas et al., 2012). In the second and third trimesters, Most et al. (2019) suggest that additional daily energy requirements differ by BMI category and range from 360 kcal·day^{-1} in underweight women to 165 kcal·day^{-1} in obese women (Most et al., 2019). The variation in recommended weight gain has been attributed to a greater fat mass accumulation and smaller variability in fat-free mass (FFM) in underweight and normal weight compared to overweight and obese women (Lederman et al., 1997; Most, Marlatt, Altazan & Redman, 2018), thus explaining the associated increased energy requirement in women with BMI <25 kg·m^2. Excessive caloric intake during pregnancy has been shown to be as detrimental to foetal health as energy deficiency, resulting in increased incidences of obesity and type 2 diabetes in later life (Marangoni et al., 2016). As such, it is clear that dietary energy intake should be moderated during pregnancy, based upon pre-pregnancy BMI, in order to maximise maternal and foetal health, through the avoidance of excessive GWG (*i.e.*, weight gain in excess of the IOM guidelines).

In many cases pregnancy results in excessive GWG; Johnson et al. (2013) showed that, 73% of 8,293 pregnancies had weight gain in excess of the IOM guidelines. Excessive GWG can result in numerous adverse outcomes, such as a higher risk of caesarean delivery, LGA babies and hypertensive disorders (Johnson et al., 2013). The cause of excessive GWG is multifactorial and includes issues such as insufficient knowledge by medical practitioners, who regularly report possessing insufficient information to provide suitable weight gain guidance to pregnant women (Holton, East & Fisher, 2017); a reluctance by midwives to address the sensitive issue of existing weight problems or GWG (Furness et al., 2011); limited or reduced physical activity as pregnancy progresses (Restall et al., 2014); and mothers believing that food cravings are necessary to meet their baby's needs (Heery, McConnon, Kelleher, Wall & McAuliffe, 2013).

Over recent years, several intervention studies have been performed to compare dietary support to routine antenatal care, with the aim of promoting appropriate GWG and optimising maternal and foetal health outcomes (Thornton, Smarkola, Kopacz & Ishoof, 2009; Abdel-Aziz 2018, Renault et al., 2014; Dodd et al., 2014; Bosaeus et al., 2015). Dietary support included lifestyle and dietary behaviour counselling provided by a nutritionist (Abdel-Aziz 2018), and the delivery of individualised nutrition regimens based on 18-24 kcal/kg body weight ensuring no woman received a dietary plan of less than 2000 kcal/day (Thornton et al, 2009). These studies provide evidence that maternal and child health can be regulated, at least in part, by limiting GWG, through nutritional means. For a complete review of nutritional interventions designed to promote weight management and improved maternal and foetal health during pregnancy see Vincze et al. (2019).

The postpartum period refers to the 12 months following childbirth, during which time any weight gained during pregnancy should be lost. Numerous studies have implemented nutrition-based interventions in the postpartum period, designed to reduce prolonged PPWR and restore pre-pregnancy BMI (Colleran, Wideman & Lovelady, 2012; Shyam et al., 2013; Wiltheiss et al., 2013, Peacock et al., 2015). Similar to during pregnancy, these cited studies have suggested that a restriction of energy intake can be used to overcome PPWR and optimise maternal and child health. Please see Vincze et al. (2019) for a full review of nutritional interventions designed to promote postpartum weight loss and subsequent maternal and child health benefits.

Seven years after pregnancy women retain, on average, 2.07kg above their pre-pregnancy weight with 23% of women experiencing >5kg weight retention (Kirkegaard et al., 2015). This prolonged PPWR is particularly true of women who experience excessive GWG and those with pre-gravid obesity (Callaway, Ellis, Wong, Hopkinson & O'Brian Smith, 2003; Widen et al., 2015). This weight retention is often augmented over subsequent pregnancies and can lead to greater degrees of overweight and obesity (Gunderson & Abrams, 2000). The inter-pregnancy period refers to the time between pregnancies and differs between multiparous women. There is growing evidence indicating substantial inter-pregnancy weight change; for example, a recent study showed that 35.4% of women with a normal pre-pregnancy BMI gained sufficient weight to classify them as overweight (~9kg weight gain) or obese (21kg weight gain) by the start of their third pregnancy (Wallace, Bhattacharya & Horgan, 2017). Obese pregnant women are at increased risk of adverse, long-term health implications, such as hypertension, cardiovascular disease and type 2 diabetes (Leddy, Power & Schulkin, 2008). In addition, their offspring are expected to experience deleterious health consequences, such as neural tube defect (Rasmussen, Chu, Kim, Schmid & Lau, 2008), foetal macrosomia (Leddy et al., 2008), increased fat mass (Hull, Dinger, Knehans, Thompson & Fields, 2008) and are more likely to be overweight or obese in later life (Whitaker, 2004). Furthermore, an interpregnancy increase of >3 BMI units, between the first and second pregnancies, has previously been associated with an increased risk of unfavourable maternal and offspring health outcomes (Oteng-Ntim et al., 2018). As such, the inter-pregnancy period appears to be an obvious time to target interventions aimed at reducing maternal weight, such that the mother, child and future offspring avoid negative health outcomes. The effect of compounding weight gain across multiple pregnancies makes it difficult to determine if delivering the same lifestyle intervention is appropriate for all women, regardless of the number of previous pregnancies. Furthermore, in multiparous women, it is often difficult to identify which pre-pregnancy BMI is the most appropriate when delivering interventions given the compounding nature of weight gain that many women experience throughout their childbearing years. Given that 64% of women had a completed family size with two or more children in 2017 (Office for National Statistics, 2018), work is urgently required to provide practitioners with up-to-date information on how to improve maternal and offspring health especially in the inter-pregnancy period.

The aim of this review was to explore the effects of dietary energy intake, resulting in excessive GWG and PPWR, on maternal and offspring health. In addition, the potential cumulative effects of GWG and PPWR on inter-pregnancy BMI were explored in those with multiple pregnancies. Herein we review the evidence relating to the determinants of excessive GWG and PPWR and discuss the health implications of the resultant obesity for both mother and child. We also provide some comment on how nutritional interventions for weight management and health could be implemented in practice, with specific consideration on the inter-pregnancy period.

2.2.3 Key Messages

- Many women experience excessive gestational weight gain, which often results in postpartum weight retention and entering subsequent pregnancies with a higher BMI. This results in a pattern of weight gain throughout the childbearing years and compromises both maternal and offspring health.

- Medical professionals, with necessary training, must improve upon the delivery of non-critical and encouraging antenatal weight management and nutritional guidance to women, especially those with overweight or obesity.

- There are a lack of nutritional interventions aimed at multiparous women. Future work must acknowledge and account for individual circumstances (*e.g.*, number of previous gestations and age of children) when designing and delivering such interventions to encourage high levels of adherence and healthy post-intervention outcomes.

2.2.4 Methods

The databases MEDLINE, PubMED, OVID, BioMed Central, Web of Science and ScienceDirect were searched for relevant studies using search terms such as ‘pregnancy’, ‘postpartum’ ‘obesity’, ‘overweight’, ‘gestational weight gain’, ‘postpartum weight retention’, ‘weight loss’ and ‘weight management’. Only articles published from 1990 onwards were included to align with the publication of the IOM weight gain guidelines during pregnancy (Institute of Medicine, 1990). Although the IOM guidelines were updated in 2009 (Institute of Medicine and National Research Council of the National Academies, 2009), it is important to include studies performed between 1990 and 2009 in order to understand the time-course of research performed since GWG became a formalised consideration by the IOM. Other inclusion criteria were human studies and full text articles published in English. We have occasionally cited other review articles to provide manageable amounts of information to healthcare professionals. We have included results from both review articles and original studies when detailing existing nutritional and weight management advice.

2.2.5 Excessive Gestational Weight Gain

The issues involved with excessive GWG are twofold. Firstly, under and normal-weight women who gain more weight than is recommended during pregnancy are three times more likely to be overweight following pregnancy (Gunderson, Abrams & Selvin, 2000), thus pregnancy is a risk factor for the development of overweight and obesity (Figure 2.1). Secondly, women with pre-gravid overweight or obesity are between two and six times more likely to experience excessive GWG (Brawarsky et al., 2005; Chasan-Taber et al., 2008; Wells, Schwalberg, Noonan & Gabor, 2006), thus being overweight or obese prior to pregnancy predisposes excessive GWG (Figure 2.1). As these two issues are often linked, the effects of obesity on maternal and foetal health, regardless of pathway, will be considered in this review. The consequences of excessive GWG highlight the urgent need for effective interventions that help women avoid weight gain in excess of recommendations in the first instance and to prevent the often-cumulative chain of events surrounding weight gain and subsequent pregnancy in the second instance.

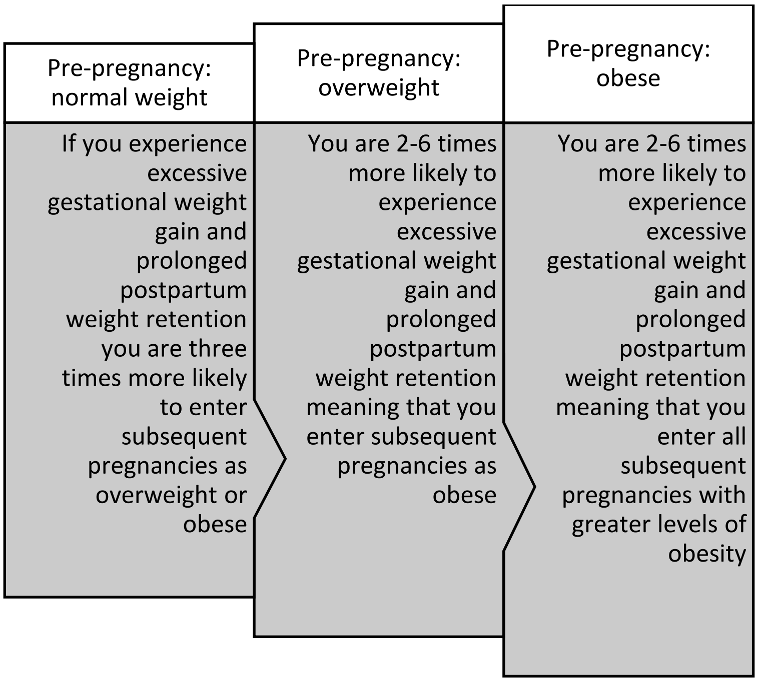

Figure 2.1 The chain of events leading to a higher body mass index category as a result of excessive gestational weight gain and postpartum weight retention over several pregnancies.

2.2.5.1 Determinants of Excessive Gestational Weight Gain

An increased risk of excessive GWG during pregnancy is associated with many risk factors including: pre-conception weight, psychosocial factors, European ethnicity, higher caloric intake, nulliparity, and smoking during pregnancy (Gaillard et al., 2013). Further detail on the association between pre-conception weight and psychosocial factors with GWG will be provided in the following sections.

2.2.5.1.1 Pre-conception weight

A 2016 review identified that excessive GWG was more likely in women who were overweight or obese at the point of conception (Samura et al., 2016), thus highlighting the need to address body mass in the inter-pregnancy period in multiparous women. In addition, when women were assessed from early pregnancy to 2 years postpartum, an inverse relationship existed between maternal body weight and both healthy eating (β=-0.57; p=0.02) and weight control (β=-0.99; p<0.0001) (Lipsky, Strawderman and Olson, 2016). Furthermore, a history of pre-gestational dieting or restrained eating was associated with excessive GWG (Mumford, Siega-Riz, Herring & Evenson, 2008). A 2018 investigation using a Food Frequency Questionnaire (Csizmadi et al., 2007), validated for preconception diets (Ramage, McCarger, Berglund, Harber & Bell, 2015), examined the association between pre-pregnancy dietary patterns and GWG (Jarman et al., 2018). Of the 1,545 women studied, those with increased consumption of both caffeinated and decaffeinated tea and coffee, milk, cream and sugar, were more likely to exceed GWG guidelines (OR 1.2 95% CI: 1.0, 1.4), however this association became non-significant following adjustment for education levels and pre-pregnancy BMI. It would be plausible to suggest that this association may be attributed to the fact that tea consumption (Vieux et al., 2019), and in some cases coffee consumption (National Coffee Association, 2020), is more common among Caucasians and these women historically experience higher GWG than women from other ethnic backgrounds (Liu 2014). In the preconception period, healthcare professionals must encourage overweight and obese women to lose weight through appropriate physical activity and dietary counselling, as well as promoting a healthy lifestyle during pregnancy for all women, with the aim of encouraging GWG within IOM recommendations (Samura et al., 2016).

2.2.5.1.2 Psychosocial factors

There is growing evidence showing that psychosocial factors, such as increased anxiety, increased depressive symptoms, lower self-esteem and body image dissatisfaction result in excessive GWG (Hill et al., 2003). Maternal age and education level are also known risk factors for excessive GWG, with women younger than 25 years at a two-fold increased risk of excessive GWG (Restall et al., 2014), and women with low education levels more likely to enter a first or second pregnancy with an unhealthy BMI compared to more highly educated women (Holowko et al., 2015). Furthermore, excessive GWG has been associated with maternal childhood adversity, which was defined as a history of physical abuse, alcohol problems, or mental illness in the household (Ranchod et al., 2016). After adjusting for socioeconomic factors in adolescence and for race and ethnicity, a 20% increase in the risk of excessive GWG was shown in women who experienced childhood physical abuse (adjusted risk ratio= 1.9; 95% CI= 1.1, 2.2). A major reason for excessive GWG may be the lack of concern about gaining too much weight during pregnancy, as many women believe that additional (*i.e.*, in excess of the recommendations) dietary intake and reduced physical activity is necessary for a healthy pregnancy (Kraschnewski & Chuang, 2014). Indeed, few antenatal behavioural interventions aimed at limiting GWG to within the guidelines have been successful, especially in women with a pre-gravid BMI over 25 $kg{\cdot}m^2$ (Daley et al., 2019; Kunath et al., 2019; Guelinckx, Devlieger, Mullie & Vansant, 2010; Kinnunen et al., 2007). Successful interventions are characterised by individualised approaches whereby, for example, feedback is provided to women based off 7-day dietary records and physical activity questionnaires (Rauh et al., 2013). Generalised approaches whereby women are provided with GWG charts and encouraged to self-weigh at home, engage in 150 minutes a week of moderate-vigorous physical activity and consume a balanced diet have proven to have little success when attempting to encourage appropriate GWG (Daley et al., 2019; Kunath et al., 2019; Guelinckx et al., 2010; Kinnunen et al., 2007). Understanding the interaction of all these risk factors, alongside individuals' motivations to adopt healthy lifestyle behaviours for the purposes of weight management has also been suggested to be important when encouraging pregnant women to limit GWG (Hill et al., 2013).

2.2.6 Postpartum Weight Retention

PPWR refers to the difference between pre-conception and postpartum weight, which is usually referred to as the difference in weight between that recorded preconception and that recorded at 12 months postpartum, although it has also been defined as 6-18 months following childbirth (Gunderson et al., 2008). Primiparous women with overweight or obesity are at a greater risk of retaining or gaining more weight in the postpartum period compared to normal weight women (Gunderson et al., 2004). Moreover, higher postpartum weights have been consistently reported in all women with excessive GWG when compared to those women with GWG within the recommended guidelines (Gunderson et al., 2008; Parker & Abrams, 1993). Greater PPWR has been noted in women with excessive GWG at 6 months (Scholl, Hedinger, Schall & Smith, 1995; Amorim, Rössner, Neovius, Lourenco & Linné, 2007; Rooney & Schauberger, 2002) and up to 15 years after pregnancy (Amorim et al., 2007; Rooney & Schauberger, 2002; Keppel & Taffel, 1993). Rooney and Schauberger (2002) showed that, 10 years after pregnancy, women who had gained below, within and in excess of the GWG recommendations were 4.1 kg, 6.5 kg and > 8 kg heavier than their pre-pregnancy weight ($p = 0.01$; Rooney & Schauberger, 2002). Furthermore, compared to women who gained weight within the IOM recommendations, those who exceeded these recommendations experienced a 3.6 kg weight increase, a 3.2cm increase in waist circumference and 3-fold increased risk of abdominal obesity 4-12 years after pregnancy (McClure, Catov, Ness & Bodnar, 2013). These data show that incremental increases in GWG above the guidelines raises the risk of PPWR and long-term obesity following childbirth.

2.2.6.1 Trimester-Specific Gestational Weight Gain and Relationship with Postpartum Weight Retention

As well as assessing GWG and its associated health risks across pregnancy (total GWG), previous studies have also analysed the link between trimester-specific changes and postpartum weight status (Walter et al., 2015). Walter et al. (2015) showed a heightened risk of PPWR in women who gained more weight during the 1st trimester compared to those who experienced greater increases in body weight during the 2nd and 3rd trimesters. In addition, each standard deviation increases in total and 1st trimester GWG resulted in a 0.85 kg (95% CI 0.07-1.63) and 2.08 kg (95% CI 1.32-2.84) increase in body weight at 3 and 7 years postpartum, in women with a healthy pre-pregnancy BMI. Hoff and colleagues (2009) indicated that, of 1,035 nulliparous women studied, who were overweight before their first pregnancy, 55% remained overweight, 33% became obese and 12% were of a normal weight/underweight by their 2nd pregnancy up to 10 years later (Hoff, Cai, Okah & Dew, 2009). The authors identified being unmarried and a birth interval of more than 18 months as risk factors for this upward trajectory in BMI by the second gestational period.

2.2.6.2 Postpartum Weight Retention and Inter-Pregnancy Weight

PPWR clearly contributes to multiparous women beginning subsequent pregnancies as either overweight or obese, especially in those who experience cumulative weight gain across multiple pregnancies (Figure 2.2) (Gunderson & Abrams, 2000). Investigations assessing parity and its relationship with PPWR are conflicting. For example, whilst one study did not find any association between parity and the risk of overweight (Gunderson et al., 2000), another study demonstrated an association between PPWR at 6 months and primiparity (Scholl, Hedinger, Schall & Smith, 1995). Lower vitamin D concentration in early pregnancy and having breastfed for less than 6 months have been identified as modifiable risk factors for PPWR (Hollis et al., 2017), whilst a US study has shown that women who were younger, on a lower income, of African American origin, were less educated and on public insurance (*i.e.*, non-modifiable risk factors) were also at an increased risk of retaining more than 20 lbs (or 9kg) at 1 year following childbirth (Endres et al., 2015). Targeting modifiable risk factors and developing social and financial support initiatives for all women in the postpartum period is of paramount importance to optimise their long-term weight management and health. Addressing weight management in the first postpartum period, especially in women with excessive GWG and in pre-gravid women with obesity, is crucial in order to begin subsequent pregnancies at a healthier BMI (Figure 2.2).

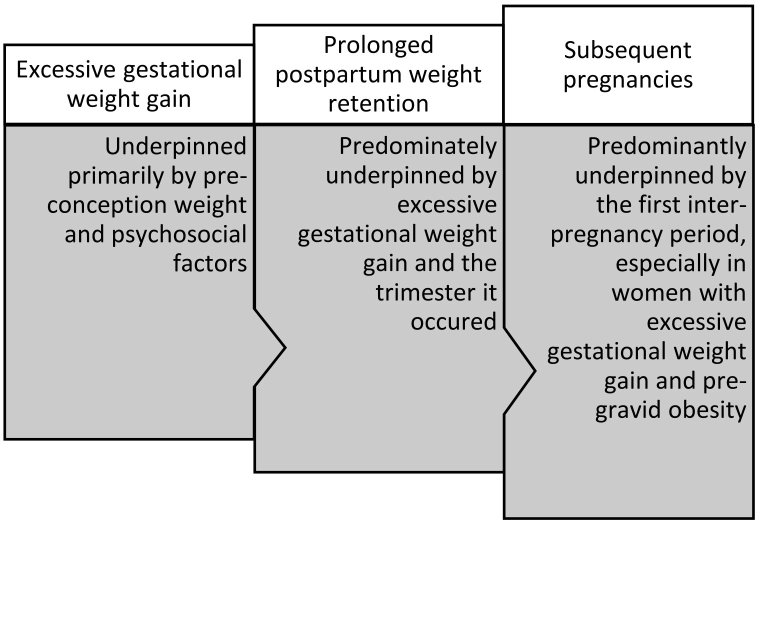

Figure 2.2 Summary of determinants of excessive gestational weight gain and prolonged postpartum weight retention, leading to cumulative inter-pregnancy weight management issues.

2.2.7 The Effects of Obesity on Maternal Health

In obstetric practice, maternal obesity is considered a common risk factor for adverse neonatal and maternal outcomes (Catalano, 2007). Healthcare teams encounter numerous challenges when supporting pregnant women with overweight and obesity, which relate to surgical, technical and medical difficulties in offering optimal pregnancy and delivery care (Fitzsimons, Modder & Greer, 2009). Table 2.1 provides a comprehensive overview of the health outcomes associated with maternal obesity. These data show the impact of pre-conception BMI on short and long-term maternal health and highlight the importance of addressing each pre-conception period, including those of subsequent pregnancies that may have been affected by excessive GWG and/or prolonged PPWR. Unfortunately, to our knowledge, there does not seem to be any literature available on the health outcomes of women who experience excessive GWG, but who subsequently return to pre-gravid BMI, be that in women of normal weight or in those with overweight or obesity.

It is important to note, both in Table 2.1 and the wider literature, that authors often utilise different weight classifications in their investigations. For example, Callaway et al. (2006) defined morbid obesity as a BMI greater than 40 kg·m^2 (Callaway, Chang, McIntyre & Prins, 2006), whilst Hoff et al. (2009) used a lower value of 35 kg·m^2 (Hoff et al., 2009). Furthermore, overweight is also categorised based on different lower-end values; for example, 26.1 kg·m^2 was used by Vahratian et al. (2004) (Vahratian, Zhang, Troendle, Savitz & Siega-Riz, 2004) whilst 25.0 kg·m^2 was used by Bhattacharya and colleagues (2007) (Bhattacharya, Campbell, Liston & Bhattacharya, 2007). In addition, it is often unclear or not reported, which pre-pregnancy BMI was used when the women were multiparous. Such variations in classification and ambiguity make it even more difficult to compare clinical outcomes across studies. Table 2.1 has been separated into pre- and post-2009 papers, such that any impact of the IOM 2009 guidelines (Institute of Medicine and National Research Council of the National Academies, 2009) can be noted. Of the included studies, there does not appear to be any noticeable differences in study design or outcomes between pre- and post-2009. Collectively, increasing BMI during pregnancy increases the risk of various adverse maternal health outcomes; notably, the risk of c-section, gestational hypertension and GDM.

Investigations exploring the long-term health outcomes following excessive GWG and PPWR have shown many unfavourable outcomes (McClure et al., 2013; Rooney, Schauberger &

Mathiason, 2005; Willett et al., 1995). Women who experience excessive GWG and fail to return to pre-pregnancy weight by 6 months postpartum are more likely to develop pre-diabetes, diabetes, pre-heart disease and heart disease within 15 years of parturition (Rooney et al., 2005). Furthermore, higher systolic and diastolic blood pressures have been shown 16 years post-pregnancy in women with excessive GWG (Willett et al., 1995), as well as in women who gained greater proportions of weight in the 1st trimester, relative to the other trimesters (McClure et al., 2013).

Table 2.1 Maternal weight status and associated health outcomes.

Reference	Weight status (BMI)	Point of Weight measurement	n	Outcome measure(s)	Conclusion
Sebire et al., 2001	NW (20–24.9 kg/m^2) OW (25–29.9 kg/m^2) OB (≥ 30 kg/m^2)	1st antenatal appointment	287,213	GDM, pre-eclampsia, anaemia, placenta previa, placental abruption, induction of labour, c-section, postpartum haemorrhage, GTI, wound infection, chest infection, UTI, pyrexia of unknown origin, pulmonary embolism, prolonged postpartum hospital stay	The following outcomes were more common (OR [99% CI]) in OW and OB respectively, compared to NW - GDM (1.68 [1.53–1.84], 3.6 [3.25–3.98]); pre-eclampsia (1.44 [1.28–1.62], 2.14 [1.85–2.47]); induction of labour (2.14 [1.85–2.47), 1.70 [1.64–1.76]); c-section (1.30 [1.25–1.34], 1.83 [1.74–1.93]); postpartum haemorrhage (1.16 [1.12–1.21], 1.39 [1.32–1.46]); GTI (1.24 [1.09–1.41], 1.30 [1.07–1.56]); wound infection (1.27 [1.09–1.48], 2.24 [1.91–2.64]); UTI (1.17 [1.04–1.33], 1.39 [1.18–1.63]).
Vahratian et al., 2004	NW (19.8-26.0 kg/m^2), OW (26.1-29.0 kg/m^2), OB (> 29.0 kg/m^2)	Pre-pregnancy	612	Labour progression	Median duration of first stage labour was significantly longer for OW (7.5 h; p<0.01) and OB (7.9 h; p<0.001) compared to NW (6.2 h).
Robinson et al., 2005	Non-obese (55-75kg) Moderate obesity (90-120kg) Severe obesity (> 120 kg)	Pre-pregnancy	142,404	Prenatal venous thromboembolism, gestational hypertension, labour induction, C-section, wound infection	Compared to non-obese women, those with moderate or severe obesity were at an increased risk (AOR [95% CI]) of prenatal venous thromboembolism (2.17 [1.30-3.63]), gestational hypertension (2.38 [2.24-2.52]), labour induction (1.94 [1.86-2.04]), C-section (1.60 [1.53-1.67]) and wound infection (1.67 [1.38-2.00]).

Callaway et al., 2006	NW (20.01-25 kg/m^2) OW (25.01-30 kg/m^2) OB (30.01-40 kg/m^2) MOB (> 40 kg/m^2)	1st antenatal appointment	14,230	Gestational hypertension, GDM,C-section, >5d hospital admission	Compared to NW, all other groups showed an increased risk (AOR, [95% CI]) of gestational hypertension (OW 1.74 [1.45-2.15], OB 3.00 [2.40-3.74], MO 4.87 [3.27-7.24]); GDM (OW 1.78 [1.25-2.52], OB 2.95 [2.05-4.25], MOB 7.44 [4.42-12.54]); C-section (OW 1.50 [1.36-1.66], OB 2.02 [1.79-2.29], MOB 2.54 [1.94-3.32]); hospital admission >5d (OW 1.36 [1.13-1.63], OB 1.49 [1.21-1.86], MOB 3.18 [2.19-4.61]).
Bergholt et al., 2007	NW (< 25 kg/m^2) MOB (> 35 kg/m^2)	1st antenatal appointment	4,341	C-section	NW were 3.8 times less likely to undergo a C-section than MOB.
Bhattacharya et al., 2007	UW (< 20 kg/m^2), NW (20-24.9 kg/m^2) OW (25-29.9 kg/m^2) OB (30-34.9 kg/m^2) MOB (> 35 kg/m^2)	1st antenatal appointment	24,241	Gestational hypertension, pre-eclampsia, induced labour, emergency C-section rates	Increasing BMI is associated with increased incidence (OR [95% CI]) of: gestational hypertension (MOB- 3.1 [2.0-4.3]), pre-eclampsia (MOB- 7.2 [4.7-11.2]), induction of labour (MOB-1.8 [1.3-2.5]) and C-section (MOB-2.8 [2.0-3.9]).
Hoff et al., 2009	UW (< 20 kg/m^2), NW (20-24.9 kg/m^2) OW (25-29.9 kg/m^2), OB (30-34.9 kg/m^2), MOB (> 35 kg/m^2)	Pre-pregnancy	1,035	Gestational hypertension, emergency C-section rate, pre-pregnancy BMI in subsequent pregnancy	Emergency C-section rate was the only outcome measure significantly affected as BMI increased from OW to OB (p<0.02). Of 1,035 OW nulliparous women, 568 (55%) remained OW during their second pregnancy, while 125 (12%) were classed as NW or UW and 342 (33%) were OB.
Blomberg, 2011	Class I obesity ($\geq$ 30 kg/m^2) Class II obesity ($\geq$ 35 kg/m^2)	1st antenatal appointment	46,595	Pre-eclampsia, C-section, instrumental delivery, excessive blood loss during delivery	Class III women who lost weight when pregnant were at a 24% lower risk (OR [95%CI]) of C-section (0.77[0.60-0.99]). They were at no greater risk for pre-eclampsia, instrumental delivery

	Class III obesity (≥ 40 kg/m²)				or excessive blood loss compared to class III women who gained weight within IOM guidelines.
Verma and Shrimali, 2012	UW (≤ 19.9 kg/m²) NW (20-24.9 kg/m²) OW (25-29.9 kg/m²) OB (30-34.9 kg/m²) MOB (> 35 kg/m²)	Not stated	784	Gestational hypertension, GDM	Compared to NW, OW and OB and MOB were at a higher risk of gestational hypertension (9.6%, 11.9% and 30.7%). Incidence of GDM in OW (1.2%), OB (7.1%) and MOB (23.0%) was also increased.
Lynes et al., 2017	Interpregnancy BMI change	Pre-pregnancy	46,521	GDM, gestational hypertension	A 1-unit interpregnancy BMI increase heightened the risk (RR [95%CI]) of gestational hypertension (1.08 [1.06-1.10]). A 3-unit increase in BMI increased GDM (1.71 [1.52-1.93]) and gestational hypertension risk (1.66 [1.42-1.94]) compared to women who experienced a ±1 change in interpregnancy BMI.
Yang et al., 2019	UW (≤ 18.5 kg/m²) NW (18.5-24.9 kg/m²) OW (25-29.9 kg/m²) OB (≥ 30 kg/m²)	1st antenatal appointment	35,099	Pre-eclampsia, GDM, C-section, ≥ 2d hospital admission	In OW and OB the risk (RR [95% CI]) of developing pre-eclampsia increased by a factor of 1.79 [1.54-2.07] and 3.50 [3.05-4.01], respectively. The risk of developing GDM increased by a factor of 1.61 [1.46-1.78] in OW and 2.66 [2.42-2.93] in OB. Compared to NW pregnant women, OW and OB women were more likely to experience a C-section (1.31 [1.24-1.37], 1.70 [1.62-1.79]) and ≥2d hospital admission (1.40 [1.23-1.58], 2.19 [1.94-2.47]).
Doi et al., 2020	NW (18.5-24.9 kg/m²) OW (25-29.9 kg/m²) OB (≥ 30 kg/m²)	1st antenatal appointment	132,899	GDM, pre-eclampsia, gestational hypertension, placenta praevia, placental abruption,	Compared with NW, OR [95% CI] of GDM was 2.14 [1.86-2.46] in OW and 8.25 [7.33-9.30] in OB. Compared with NW, OR of pre-eclampsia and

induction of labour, C-section (elective and emergency)	gestational hypertension was 1.46 [1.32-1.62] and 1.61 [1.49-1.74] in OW, and 2.07 [1.87-2.29] and 2.48 [2.30-2.68] in OB, respectively. The OR of placenta praevia and placental abruption was not statistically significant for OW and OB when compared to NW. The OR of induction of labour was significant for OW (1.28 [1.23-1.33]) and OB (1.69 [1.62-176]). OW had ORs of 1.34 [1.29-1.39] for an elective c-section and 1.82 [1.74-1.91] for an emergency c-section. Corresponding ORs for women with obesity were 1.80 [1.73-1.88] and 3.14 [3.00-3.29], respectively.

Abbreviations: UW- underweight, NW- normal weight, OW- overweight, OB- obese, MOB- morbidly obese, C-section- caesarean section, CI- confidence interval, OR- odds ratio, AOR- adjusted odds ratio, RR- risk ratio, GDM- gestational diabetes mellitus, UTI- urinary tract infection, GTI- genital tract infection, n- sample size

2.2.8 The Effects of Maternal Obesity on Child Health

Maternal lifestyle habits, diet and weight status are significant predictors of offspring health (Marangoni et al., 2016). Excessive GWG and obesity during pregnancy are associated with numerous adverse foetal effects, which lead to higher incidences of neonatal intensive care unit admissions (Verma & Shrimali, 2012; Usha Kiran et al., 2005). Maternal weight is known to affect several offspring outcomes, and these are presented in Table 2.2.

Links between foetal overgrowth and macrosomia have been shown to increase the risk of developing insulin resistance and type 2 diabetes, renal disease and elevated blood pressure (Garcia-Vargas, Addison, Kurukulasuiya & Sowers, 2012). The association between maternal obesity and GDM with macrosomia is primarily due to more blood glucose passing through the placenta into the foetal circulation (Kc, Shakya & Zhang, 2015). The additional glucose is then stored as foetal body fat causing macrosomia. Foetal macrosomia has been linked to glucose intolerance in later life and a transgenerational transference of diabetes risk exists as a result of epigenetic alterations (Bouchard et al., 2010; Uzelac et al., 2010; Houde, Hivert & Bouchard, 2013).

The effects of *in utero* programming extend beyond gestation and parturition and have been shown to affect childhood (de Boo & Harding, 2006), and adult health (Barker, 1990). Whilst the Barker Foetal Origins Hypothesis was initially concerned with low birth weights, there is evidence to suggest that high birth weights also result in adverse health-related outcomes, such as childhood obesity and heart disease during adolescence and beyond (Leddy, Power & Schulkin, 2008). The link between macrosomia and overweight and obesity in later life is well established (Schellong, Schulz, Harder & Plagemann, 2012). The findings from a systematic review and meta-analysis of 643,902 individuals in 26 countries indicated that high birth weight (>4,000 g) is associated with an increased risk of overweight in later life (OR= 1.66; 95% CI 1.55-1.77; Schellong et al., 2012). This relationship may be caused by long-term alterations in the ratio of fat to lean body mass, control of appetite by the central nervous system, and the function and structure of the pancreas (Oken & Gillman, 2003). These changes can have long-term, adverse implications on cardiometabolic health, including the dysregulation of glucose and insulin homeostasis, and the development of hypertension and vascular dysfunction (Drake & Reynolds, 2010). These findings highlight the need to address, in a non-judgmental and supportive manner, the issue of body weight in pre-gravid women with obesity and in multiparous women who have experienced excessive GWG and PPWR and are subsequently categorised as overweight or obese, such that they are made aware of these risks and sources of advice and support.

Table 2.2 Maternal weight status and associated offspring health outcomes.

Reference	Maternal weight measure	n	Outcome measure(s)	Conclusion
Cogswell et al., 1995	Interpregnancy BMI change	925,065	Birth weight	An interpregnancy BMI increase of >3 units was associated with a greater risk (OR [95% CI]) of LGA offspring (1.85 [1.71 to 2.00], p<0.001) and macrosomia (1.54 [0.939-2.505]) compared with women who did not change BMI category or experienced a ±2 unit change.
Whitaker, 2004	NW (19.8-26 kg/m^2) OW (> 26-29 kg/m^2) OB (> 29 kg/m^2)	53,541	Birth weight	The incidence of low birth weight (< 2500g) decreased from 2.7% NW to 2.1% in OB. Women who experienced ≥ 40lbs GWG were three times more likely (95% CI 2.3 to 4.7) to deliver a LGA baby compared to women who gained 25-29 lbs.
Reynolds et al., 2010	23.3±3.7 kg/m^2 (at 1st antenatal visit)	276	Offspring adiposity	The higher the mother's BMI at the first antenatal visit, the greater the level of offspring adiposity 30 years after birth (body fat % rising by 0.35% per $kg \cdot m^{-2}$; $p \leq 0.001$), which was also independently associated with excessive GWG (p = 0.02).
Gaudet et al., 2014	UW (< 18.5 kg/m^2) NW (18.5-24.9 kg/m^2) OW (25-29.9 kg/m^2) OB (30-39.9 kg/m^2) MOB (≥ 40 kg/m^2)	8,494	Childhood obesity	At 2, 3 and 4 years of age childhood obesity prevalence was 9.5%, 12.5%, and 14.8%, respectively. At age 4, 24.1% were obese if their mothers had been obese in their 1st trimester of pregnancy, whereas only 9% of children of normal-weight mothers were obese.
Eriksson et al., 2014	≤ 24 kg/m^2 24.1-26 kg/m^2 26.1-28 kg/m^2 > 28 kg/m^2	13,345	CVD (CHD, stroke), type 2 diabetes	There was a trend (per kg/m^2 increase in maternal BMI) towards an increased incidence of CVD (p=0.02), CHD (p=0.003), and type 2 diabetes (p=0.004) in the offspring of mothers with higher BMI's.
Lutsiv et al., 2015	NW (20-24.9 kg/m^2) OW (≥ 30 kg/m^2)	8,204,116	Pre-term birth <37 weeks, LGA offspring, SGA offspring	LGA incidence (RR [95% CI]) was higher in class III obesity than classes I and II (1.37 [1.29-1.4]; 1.30 [1.24-1.36]), and SGA incidence was lower (0.89 [0.84-0.93]) compared to class I.

	OB (≥ 35 kg/m^2) MOB (≥ 40 kg/m^2)			
Patel et al., 2016	UW/NW (<25.0 kg/m^2) OW/OB (>25.0 kg/m^2)	1,581	NAFLD	Maternal overweight and obesity and pre-pregnancy BMI were significantly associated with a greater risk of offspring NAFLD ($p<0.05$).
Oteng-Ntim et al., 2018	UW (≤ 19.9 kg/m^2) NW (20-24.9 kg/m^2) OB (> 30 kg/m^2)	>1,000,000	Birth weight	Maternal obesity and foetal overgrowth are associated; The likelihood of delivering a macrosomic offspring is increased by 142% for LGA, 117% for birth weight ≥ 4000g and 277% for birth weight ≥4500g.
Yang et al., 2019	UW (≤ 18.5 kg/m^2) NW (18.5-24.9 kg/m^2) OW (25-29.9 kg/m^2) OB (≥ 30 kg/m^2)	35,099	Extreme PTB (<32 weeks), LGA offspring, admission to SCN/NICU	Babies born to OW and OB women were at a greater risk (RR [95% CI] OW, RR [95% CI] OB) of extreme PTB (1.16 [0.84-1.61], 1.95 [1.42-2.67]), LGA (1.60 [1.46-1.76], 2.14 [1.94-2.35])and SCN/NICU admission (1.07 [0.98-1.16], 1.34 [1.22-1.47]), compared to NW.
Doi et al., 2020	NW (18.5-24.9 kg/m^2) OW (25-29.9 kg/m^2) OB (≥ 30 kg/m^2)	132,899	SGA, LGA, pre-term delivery (<37 weeks), post-term delivery (>42 weeks), low Apgar score (<7 @ 5 min)	Odds (OR [95% CI]) of SGA decreased among OW (0.81 [0.78-0.85]) and OB (0.79 [0.74-0.83]), respectively. Odds of LGA increased among OW (1.27 [1.23-1.30]) and OB (1.53 [1.48-1.58]). Compared with NW, adjusted OR of pre-term delivery was 1.02 [0.96-1.07] in OW and 1.11 [1.05-1.18] in OB. Adjusted OR for post-term delivery was 1.57 [0.93-2.68] in OW and 1.47 [0.78-2.77] in OB. Being OW (0.95 [0.92-0.99]) or OB (0.96 [0.93-1.00]) was associated with reduced odds of low Apgar scores, compared to NW.

Abbreviations: UW- underweight, NW- normal weight, OW- overweight, OB- obese, MOB- morbidly obese, CI- confidence interval, OR- odds ratio, RR- risk ratio, NICU- neonatal intensive care unit, LGA- large-for-gestational-age, SGA- small-for-gestational-age, CHD- coronary heart disease, CVD- cardiovascular disease, NAFLD- non-alcoholic fatty liver disease, n- sample size, PTB- preterm birth, SCN- special care nursery, NICU- neonatal intensive care unit

2.2.9 Translating Nutritional and Weight Management Advice for Mothers with Obesity

Despite pregnancy being described as an extremely effective “teachable moment” for promoting positive behaviour change (Phelan, 2010), healthcare professionals have expressed unique challenges when addressing maternal obesity. These challenges include a lack of knowledge around the treatment and care of mothers with obesity (Holton et al., 2017), being unsure how to raise the sensitive issue of weight (Furness et al., 2011), and being ill-equipped to care for high-risk pregnancies (Herring et al., 2010; Power, Cogswell & Schulkin, 2006). Similarly, pregnant women with obesity have described feelings of humiliation, discomfort, and anxiety during antenatal appointments (Mulherin, Miller, Barlow, Diedrichs & Thompson, 2013; Dotlic et al., 2014). Women with a BMI >30 $kg{\cdot}m^2$ have previously expressed feelings of disappointment with their pregnancy care, particularly as they felt that their informational expectations had not been met and that they had encountered healthcare providers that seemed uninterested and who were not confident when delivering advice (Lavender & Smith, 2016). These women agreed to participate in a study focused on weight change, which demonstrates their readiness for behaviour change, although they mentioned receiving little, and sometimes conflicting, lifestyle advice, which would suggest that the National Institute of Health and Care Excellence (NICE) weight gain recommendations are not always being utilised in routine healthcare (NICE, 2010).

In order to address some of the gestational weight management issues described by healthcare professionals and pregnant new mothers, numerous studies (*e.g.*, Dodd et al., 2014; Renault et al., 2014; Peacock et al., 2015) have utilised nutritional interventions aimed at limiting GWG and/or promoting postpartum weight loss yet few have focused on interventions exclusively for multiparous women with cumulative weight gain and resultant pregnancy related obesity (Lombard, Deeks, Jolley, Ball & Teede, 2010).

The route of delivery of these weight management services is also important. Olander et al. (2012) examined the characteristics of healthy eating services and the support that UK women need in order to successfully adhere to such services or programmes and maintain a healthy weight during pregnancy (Olander, Atkinson, Edmunds & French, 2012). They showed that women prefer practical sessions in a convenient location, ideally delivered by other mothers. The women wanted a routine of eating healthily during pregnancy, with the hope that it would be easier to maintain these new dietary habits after the arrival of their baby. However, it would likely be difficult to identify a convenient location for all women and it would be reasonable to suggest that this approach is not scalable or easily implemented into routine antenatal care, especially given the additional time required from the service delivery team to implement such an approach. Research by Atkinson et al. (2013) has shown that many women wish to engage in weight management services during pregnancy but fail to adhere to programmes as a result of a number of perceived barriers, which included inadequate explanations of the service and preferring group-based programmes (Atkinson, Olander & French, 2013). These studies show that particular focus must be given to the environment in which an intervention is delivered alongside the content of the intervention itself.

In various areas of healthcare, the use of group-based technological support (*e.g.* WhatsApp and Facebook groups) is becoming more popular, including to enable the delivery of information and support for pregnant women outside of antenatal visits (Patel et al., 2018). This approach may be especially effective as it is less time intensive for the service delivery team than face-to-face strategies, a suitable location for the delivery of the service is not required, and women can engage with the group and its content at times most suitable for them.

Goldstein et al (2016) examined the integration of large-scale meta-analyses into clinical practice and the need to implement lifestyle interventions into routine antenatal care. They recognised that the pre-conception period offers an opportune time to assess and manage weight-related health conditions; including hypertension, type 2 diabetes and sleep apnoea (Goldstein, Teede, Thangaratinam & Boyle, 2016; Kurukulasuriya, Stas, Lastra, Manrique & Sowers, 2011). They noted, however, that no evidence exists to support specific intervention designs or models of pre-conception care to improve the pregnancy outcomes of overweight and obese women. Harrison et al. (2017) recognised the need to accelerate the implementation of antenatal lifestyle interventions into routine pregnancy care. They developed a framework that included six key steps centred around formative research, knowledge synthesis and generation, implementation research, dissemination and scale-up and finally, evaluation (Harrison et al., 2017) to facilitate the implementation of antenatal lifestyle interventions into routine pregnancy care.

It would appear from the evidence discussed herein that healthcare professionals need to be better equipped with the necessary skills and knowledge to provide universal, easy to understand information when discussing GWG and a healthy lifestyle with pregnant women.

For example, Baker (2011) developed an antenatal care pathway for obese pregnant women but identified one limitation as the need to include more time educating the service delivery team to ensure that all appropriate and necessary information is delivered to service users. Careful consideration of the location of interventions is also necessary. Home-based delivery of lifestyle programmes appears to result in better long-term adherence in obese individuals when compared with centre-based programmes (Perri, Martin, Leermakers, Sears & Notelovitz, 1997). A combination of group and individual sessions has been suggested rather than one approach alone (Tate et al., 2017), and combining face-to-face and online delivery of intervention information has gained recent popularity and demonstrated success in weight loss settings (Williams, Hamm, Shulhan, Vandermeer, & Hartling, 2014; Hales, Davidson & Turner-McGrievy, 2014). Lastly, the use of Patient and Public Involvement (PPI) in the design of GWG and postpartum weight loss interventions must be considered given its success in other areas of healthcare (Evans et al., 2018; Boudioni, McLaren & Lister, 2017). Given the lack of intervention studies involving exclusively multiparous women, engaging with the population through PPI is crucial to understand their thoughts and opinions regarding the implementation of lifestyle programmes. It is imperative that barriers to participation are addressed, for example a lack of time and childcare, and strategies are developed to ensure that these women can participate with minimal interruption to their role as a mother.

Although there are many systematic reviews and studies (Flynn et al., 2016; Dalrymple, Flynn, Relph, O'Keeffe, & Poston, 2018; Vincze et al., 2019) on this topic, the optimum nutrition-based intervention remains unknown, which might be due to several methodological issues, such as the use of self-report instruments for dietary assessment, high attrition rates, level of quality of available studies, issues with external validity and lack of long-term follow-ups, which would undoubtedly strengthen our understanding of the impacts of pregnancy and postpartum lifestyle interventions on health in later life. Moreover, lifestyle interventions aimed at limiting GWG are delivered to all pregnant women irrespective of the number of previous gestations. This should be reconsidered as it would be reasonable to suggest that women encounter barriers to a healthy lifestyle in varying intensities according to the number and age of the children they must care for. As such, individualised approaches are required to ensure that personal circumstances are accounted for and healthy post-intervention outcomes are encouraged for all women. Although the design of such approaches may take more time and may require more resources and input from service delivery teams, it has been evidenced herein that generalised nutritional approaches are largely ineffective, and so individualised, however adaptable, approaches must be developed to improve post-intervention outcomes, specifically in multiparous women. Formative work, for example PPI work, should also be regarded as a necessary step to enable the development of successful lifestyle interventions in this population. Moreover, in nulliparous women, pre-pregnancy BMI is used to determine a woman's eligibility for a study. Further investigation is required to identify if BMI prior to the first gestational period, postpartum BMI or BMI at study enrolment is most appropriate when studying multiparous women.

2.2.10 Limitations

Whilst we recognise that narrative reviews cannot be truly used as scientific evidence, we believe that this review has provided an experiential perspective without presenting bias in our interpretations of the topic (Ferrari, 2015). Narrative reviews are often criticised due to a lack of detail regarding the assumptions and selections made when developing the review, therefore we have adopted a methodological approach to ensure that readers can accurately interpret and apply the works and recommendations contained herein (Ferrari, 2015). Furthermore, we have provided a scoping overview of many topics that we believe to be important when addressing the effect of dietary intake on GWG and PPWR in multiparous women, but for a more comprehensive insight into specific areas of the review further investigation is required.

2.2.11 Conclusion

Despite having recommendations for GWG based upon pre-pregnancy BMI, it is evident that many women experience excessive weight gain during pregnancy. GWG is the strongest predictor of PPWR and excessive GWG often results in prolonged PPWR. Sustained weight retention can result in women beginning subsequent pregnancies overweight or obese. Many women experience cumulative weight gain across several pregnancies, which can lead to adverse maternal and offspring outcomes. As such, there is a crucial need to provide effective support on weight management to mothers before, during and after pregnancy to optimise short- and long-term maternal and offspring health. Maternal nutrition and weight management must be treated as key priorities during antenatal care, and medical professionals should improve upon the delivery of non-critical, simple and encouraging guidance to women, especially those with a BMI >25 $kg{\cdot}m^2$ (Walker, Kumar, Blumfield & Truby, 2018). These changes to healthcare practice have the potential to lower the prevalence of overweight and obesity in women and their children and are vital if society is going to interrupt the current generational cycle of obesity (Melzer & Schutz, 2010; Josefson, 2011).

2.2.12 References

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2.3 Exercise interventions for weight management during pregnancy and up to 1 year postpartum among normal weight, overweight and obese women: an updated systematic review.

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2.3.1 Abstract

Objectives

To provide an updated systematic review from work published by our research group in 2015 on studies employing exercise interventions for weight management in pregnancy and postpartum women.

Methods

We conducted a systematic review of randomised controlled trials evaluating the effects of an exercise intervention delivered during pregnancy or up to one year postpartum on GWG and postpartum weight management in normal weight, overweight and obese women. PubMed, Scopus, Central Register of Controlled Trials (CENTRAL) and Web of Science trial registries were searched for studies published between September 2013 and June 2020. No restrictions were set on type, intensity, duration or frequency of exercise intervention. Only studies that targeted body weight or mass as a primary outcome were included. Body weight (kg) and/or BMI (kg/m^2) change were considered.

Results

Thirteen studies were included in this review: 11 during pregnancy and two in the postpartum period. Exercise reduced GWG in five of the pregnancy studies and induced significant weight loss in one of the postpartum studies. Across studies, there were large disparities in exercise modality, frequency and duration, although moderate intensity exercise was consistently employed.

Conclusion

Only a relatively small number of studies showed positive effects of exercise strategies on weight management during pregnancy and in the postpartum period, and due to disparities in the characteristics of exercise programs, it is difficult to conclude the most effective and appropriate intervention during this time. Although, the delivery of specific, goal-orientated intervention approaches may be most efficacious in producing successful outcomes.

2.3.1.1. Significance

What is already known on this subject?

In many cases pregnancy results in excessive GWG and long-term PPWR, which has a negative impact on maternal and offspring health.

What this study adds?

Despite more work being done to investigate the effect of exercise on antenatal and postnatal weight management, only around half of interventions delivered during pregnancy and in the postpartum period were successful in achieving appropriate GWG and postpartum weight loss. Future work must look to draw upon successful components of previous interventions, whilst involving relevant stakeholders, to develop efficacious exercise strategies that encourage appropriate antenatal and postnatal weight management.

KEYWORDS: Pregnancy, Postpartum, Exercise Interventions, Weight Management

2.3.2 Introduction

In 2015, we investigated the effects of an exercise intervention compared to routine care or another intervention on GWG in normal weight, overweight and obese women (Elliott-Sale et al., 2015). This review was designed to determine if exercise could be used to limit excessive GWG and reduce prolonged PPWR. Based upon the five included studies, we showed that exercise during pregnancy significantly reduced GWG but did not significantly enhance weight loss following childbirth. These findings led us to recommend that further randomised controlled trials (RCTs) were necessary to establish the efficacy of exercise interventions as a weight management tool both during and following pregnancy.

Since we conducted and published our original review, worldwide and maternal obesity rates have risen. In 2016, more than 1.9 billion adults were classified as overweight or obese (World Health Organisation 2020). The current prevalence of obesity in women is 15%, which represents a threefold increase since 1975 (World Health Organisation 2020). Women of reproductive age represent a sub-population with one of the highest increases in obesity rates in recent years (NCD Risk Factor Collaboration 2016). Public Health England (Public Health England, 2019) showed that, in 2017, 21.6% of women were obese at the time of antenatal booking, which represents a 6% increase from 10 years earlier (Heslehurst et al. 2010).

The rising prevalence in pre-gravid obesity might be partially caused by inadequate guidance on appropriate GWG. The GWG guidelines published in 2009 by The IOM (Institute of Medicine (US) and National Research Council (US) Committee to Reexamine IOM Pregnancy Weight Guidelines 2009) are still the most up-to-date recommendations for weight gain during pregnancy. These guiding principles have, however, received criticism for being too conservative for overweight and obese women. Several groups (Bodnar et al. 2010; Kiel et al. 2007; Oken et al. 2009) have suggested that less GWG, weight maintenance or even weight loss could be more appropriate for overweight and obese pregnant women, and some authors (Faucher and Barger 2015) have proposed that the IOM guidelines should be modified further according to obesity class.

Recent data have shown that women who are overweight or obese are more likely to experience excessive GWG in comparison to normal weight women (Deputy et al. 2015; Simko et al. 2019). Excessive GWG is associated with, amongst other adverse outcomes, maternal hypertension and LGA offspring (Goldstein et al. 2017; Ren et al. 2018), as well as higher PPWR (Ronnberg et al. 2016). Excessive GWG and PPWR have been shown to result in an elevated BMI up to 15 years following childbirth (Widen et al. 2015), which is associated with adverse long-term health issues including an increased risk of breast and colon cancer, type 2 diabetes and cardiovascular disease (Hruby et al., 2016).

Given the dearth of knowledge in this area, the increased occurrence of pre-gravid obesity in recent years, and the implications of maternal obesity for maternal and offspring health, it is evident that there is a continued need to investigate antenatal and postnatal weight management strategies and to provide evidence-based advice for exercise-based interventions. The current review was conducted to provide an update to the systematic review published by Elliott-Sale et al. (2015). Given the small number of studies (n = 5) included in the Elliott-Sale et al. (2015) review, it was important to add to the dataset by assessing the most recent data published since 2015, in order to provide a more in-depth view of current knowledge. Therefore, we performed a systematic literature search of RCTs published between 2013 and 2020 in order to analyse the effects of an exercise intervention compared to routine care or another intervention on GWG and postpartum weight retention in normal weight, overweight and obese women.

2.3.3 Methods

This review conforms to PRISMA guidelines (Moher et al. 2009), regarding the report of a systematic review on intervention studies, and follows the search and selection methods outlined in Elliott-Sale et al. (2015). An abridged version of the methodology is described below for convenience.

2.3.3.1 Search strategy

The following databases were searched: PubMed, Scopus, CENTRAL and Web of Science. The search was set between September 2013 and June 2020, providing an update to the Elliott-Sale et al. (2015) publication, who performed their last search in September 2013. Search terms included: ‘physical activity’, ‘exercise’, ‘pregnancy’, ‘pregnant women’, ‘postpartum’, ‘weight’, ‘weight management’, ‘weight loss’, ‘overweight’ and ‘obesity’. The search was restricted to papers published in English, using human participants.

2.3.3.2 Study selection

Three investigators (SJH, ES, KJE-S) independently screened (i) the titles and abstracts and then (ii) the full text of all potentially eligible randomised or quasi-randomised controlled studies. Any disagreements were resolved by discussion. Studies were included where the exercise intervention was compared with routine care or another intervention. Only exercise interventions that aimed to manage maternal weight during pregnancy and in the postpartum period were included. There were no restrictions set on the type, duration, frequency, intensity, setting or mode of exercise. Healthy pregnant and postpartum women, aged ≥ 18 years and free from medication known to influence weight or exercise performance were included. Postpartum referred to the 12 months following childbirth. Normal weight (BMI 18.50-24.99 kg/m^2), overweight (BMI >25 kg/m^2) and obese (BMI > 30 kg/m^2) primigravidas and multigravidas, and nulliparous, primiparas and multiparas women were included.

2.3.3.3 Data extraction and risk of bias assessment

The primary outcomes were body weight and BMI (kg/m^2). One reviewer (SJH) completed the data extraction, and all relevant information was extracted using a standardised data extraction form. Information on trial design (eligibility criteria (see Table 2.3), setting, sample size, length of follow-up), participant characteristics (*i.e.*, age, weight status, and attrition rates), intervention type (*i.e.*, intervention and control components, adherence, and timings) and outcomes (*i.e.*, GWG, BMI change, and weight loss) were collected. Study authors were contacted in instances where insufficient information was obtained through identified sources. SJH assessed risk of bias using the Cochrane risk of bias tool, which evaluates data quality based off five domains: randomisation, allocation concealment, double blinding, follow-up and overall bias. Each criteria was assigned the grade A, B, C, or D; A- low risk or adequate or stated, B- moderate risk or unclear or not stated, C- high risk or not used or inadequate, D (only allocation concealment) - not used. To assess the quality of evidence, SJH and KJE-S used the criteria outlined in the Consolidated Standards of Reporting Trials (CONSORT) to assess the strength of the evidence provided. Items 6b and 11b were removed, as they were not applicable to any of the included studies. Neither the Cochrane risk of bias tool or CONSORT criteria were employed to exclude any studies that did not meet their requirements or standards. Any differences between reviewers were resolved through discussion until a consensus was reached.

Table 2.3 PICOS model of eligibility criteria

	Inclusion	Exclusion
Population	Healthy pregnant and postpartum women, free from any pregnancy-related complications or medical conditions or not currently taking any medications known to affect body weight or exercise performance. Normal weight (BMI 18.50-24.99 kg/m^2), overweight (BMI >25 kg/m^2) and obese (BMI > 30 kg/m^2) primigravidas and multigravidas, and nulliparous, primiparas and multiparas women.	Studies including women <18 years old. Studies on underweight women (BMI <18.5 kg/m^2) and women at risk of giving birth to low birthweight babies (<2500g) or insufficient gestational weight gain (<11kg for normal weight women).
Intervention	Interventions involving exercise aimed to manage maternal weight during and following pregnancy, such as training programmes and counselling in any setting.	Interventions not specifically designed to target or affect weight. Interventions involving mothers of young children when the postpartum period was not specified.
Control	Group not receiving the intervention treatment or receiving routine antenatal or postnatal care.	
Outcome	Change in body weight (kg) or change in BMI (kg/m^2).	Any studies that reported outcomes other than change in body weight or BMI as a primary outcome.
Study Design	RCTs and quasi-randomised trials published in English using human participants.	Reviews, abstracts from conference proceedings.

2.3.4 Results

2.3.4.1 Description of included studies

Our search identified 919 records, and following the removal of duplicates, the titles and abstracts of 887 articles were screened. Following phase 1, 853 studies were excluded due to being retrospective, non-randomised, qualitative, duplicates or baseline studies. The eligibility of 34 full-text papers was assessed, with 21 papers excluded based on: not being conducted to specifically influence weight; having combined exercise and diet interventions; being study protocols; including participants under 18 years of age; and not being published in English. Thirteen papers were included in the review, which were published between December 2013 and October 2019. Figure 2.3 details the search strategy, including the study selection process and reasons for exclusion. The characteristics of the excluded studies are summarised in Table 2.4.

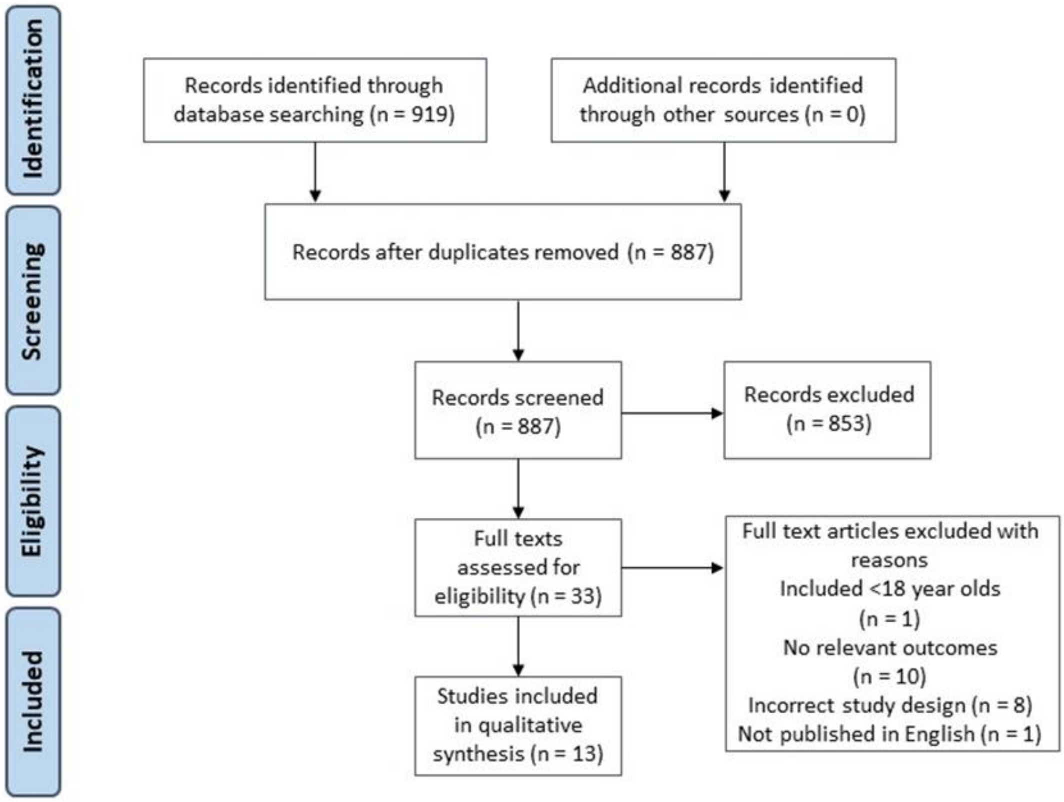

Figure 2.3 Flow of articles from identification to inclusion

Table 2.4 Reasons for excluding full-text studies.

Study	Reason for Exclusion
Aparicio *et al.* (2016)	Study protocol outlining the methodology for the GESTAFIT, which aimed to assess the effects of an exercise intervention in overweight and obese pregnant women on maternal and foetal health markers
Barakat *et al.* (2016)	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to examine the impact of supervised exercise throughout pregnancy on the incidence of pregnancy-induced hypertension.
Bertz *et al.* (2015)	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to use data from the LEVA trial to evaluate the short- and long-term effects of the intervention on macronutrient intake and report the diet achieved with the dietary treatment in relation to the Nordic Nutrition Recommendations
Bisson *et al.* (2015)	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to evaluate whether a supervised exercise program during the 2nd trimester of pregnancy results in higher physical activity levels throughout pregnancy in women with obesity
Da Silva *et al.* (2017)	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to evaluate the efficacy of the PAMELA RCT on preventing preterm birth and pre-eclampsia (primary outcomes) and other maternal and foetal outcomes
Daly *et al.* (2017)	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to evaluate whether a supervised exercise intervention for women with BMI $\geq$ 30 kg/m^2 reduced fasting plasma glucose concentration at 24-28 weeks' gestation in the intervention group compared with women undergoing routine prenatal care
DeRosset *et al.* (2013)	Combined diet and exercise intervention
Gesell *et al.* (2015)	Combined diet and exercise intervention
Ghaderpanah *et al.* (2017)	Not published in English
Harden *et al.* (2014)	Combined diet and exercise intervention
Harrison *et al.* (2014)	Combined diet and exercise intervention (HeLP-her Study)
Joshi *et al.* (2018)	Combined diet and exercise intervention (RENEW Study)
Keller *et al.* (2014)	Non-intervention study. The purpose of this study was to describe the correlates of overweight and obesity in postpartum Latinas in the first 6 months following childbirth
Kong *et al.* (2014)	The intervention did not intend to manage maternal weight during pregnancy or postpartum; rather to increase moderate-intensity physical activity during pregnancy via a walking intervention
Nobles *et al.* (2017)	The intervention did not intend to manage maternal weight during pregnancy or postpartum; rather to evaluate the impact of the B.A.B.Y. RCT on gestational diabetes risk

Rodriguez-Blanque *et al.* (2020)	The intervention did not intend to manage maternal weight during pregnancy or postpartum; rather to investigate the influence of a water-based exercise program on the rate of spontaneous birth
Ronnberg *et al.* (2014)	Study included under 18's
Ronnberg *et al.* (2016)	Postpartum follow-up of an antenatal intervention
Seneviratne *et al.* (2015)	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to evaluate the effect of antenatal exercise on offspring birthweight (primary outcome) and other foetal and maternal outcomes in overweight and obese women
Wang *et al.* (2017)	The intervention did not intend to manage maternal weight gain during pregnancy or postpartum; rather to investigate the effect of exercise on the incidence of gestational diabetes in overweight and obese pregnant women

Abbreviations: GESTAFIT, GESTAtion and FITness; RCT, randomised controlled trial; LEVA, Lifestyle for Effective Weight loss during Lactation; PAMELA, Physical Activity for Mothers Enrolled in Longitudinal Analysis; HeLP- her, Healthy Lifestyle Program; RENEW; Revolutionizing Exercise and Nutrition Everyday in Women; B.A.B.Y., Behaviours Affecting Baby and You.

2.3.4.2 Interventions

Table 2.5 shows the characteristics of the included studies. In brief, participants in the pregnancy studies were recruited between 5- and 19-weeks' gestation and all interventions lasted between 15 and 30 weeks. All studies included singleton pregnancies and only one trial included both nulliparous and multiparous women (Dekker Nitert et al. 2015). Participants in the postpartum studies were between 6 weeks and 1-year postpartum. Between 65% and 95% of women reported exclusive or partial breastfeeding. Postpartum interventions lasted between 40 days and 18 weeks. Baseline physical activity levels ranged from 'unspecified', to sedentary, to physically active.

Exercise interventions initiated during pregnancy had the following characteristics: duration 50-90 min, frequency 3-5 times per week and moderate intensity; 55-60% maximal heart rate, <60% or <70% age predicted maximum heart rate, <80% maximal capacity, 10-12 or 12-14 on the 6-20 Borg Scale, 10,000 daily steps. Interventions were predominantly aerobic, with some additional resistance exercises (*e.g.*, bicep curls, arm side lifts, hamstring curls, bench presses). Six of the pregnancy interventions were performed in supervised groups, three interventions were performed in both group and individual settings and two were individual focused. One postpartum study involved a progressive resistance exercise program (LeCheminant et al. 2014) and the other delivered an at-home active video game intervention (Tripette et al. 2014).

Most studies included two comparisons: exercise versus routine care (control). Pawalia et al. (2017) and Renault et al. (2014) had three comparison groups (diet and exercise, exercise and control) and Simmons et al. (2017) had four comparison groups (diet and exercise, diet, exercise and control). As the aim of the review was to investigate the effects of exercise training on weight management, only the exercise and control data were considered. Of note, LeCheminant et al. (2014) included an active control group and compared resistance training (intervention group) to flexibility training. Brik et al. (2019) and Pawalia et al. (2017) conducted follow-up measures at 6 weeks and 2 months postpartum, although only the pregnancy data was considered here. Simmons et al. (2017) assessed outcomes at both 24-28- and 35-37-weeks' gestation; only the data at 35-37 weeks was considered here. Discrete measures, such as fat and lean body mass (Tripette et al. 2014), waist and hip circumference (Pawalia et al. 2017; Tripette et al. 2014) and the number of women who exceeded the 2009

Institute of Medicine weight gain guidelines (Ruiz et al. 2013; Renault et al. 2014; Dekker Nitert et al. 2015) were not included in the analysis.

Table 2.5 Characteristics of included studies (divided into pregnancy and postpartum studies)

	Study and setting	Population	Intervention	Weight change (kg) (mean±SD)	Adherence rates (%)
Pregnancy studies	Bacchi et al. (2018) Argentina	NW/OW I: n=49 C: n=62	*Duration:* 85 sessions (~30 weeks) *Mode:* aquatic aerobic and strengthening-exercises (SE)/swimming *Frequency:* 55-60 min 3 days/week *Intensity:* light-moderate intensity according to Borg rating of perceived exertion (RPE) scale *Delivery mode:* Group *C:* Standard prenatal care	GWG: I: +12.7 ± 2.6 C: +13.9 ± 4.3 p= NS	>85
	Barakat et al. (2014) Spain	NW/OW/OB I: n=107 C: n=93	*Duration:* ~30 weeks *Mode:* aerobic/SE *Frequency:* 55-60 min 3 days/week *Intensity:* light-moderate intensity 55-60% maximum heart rate (HRmax) *Delivery mode:* Group *C:* Standard prenatal care, general nutrition and exercise counselling from healthcare provider, reported exercise levels once per trimester	GWG: I: +11.7 ± 4.1 C: +13.7 ± 9.6 p= NS	>95
	Barakat et al. (2019) Spain	NW/OW I: n=234 C: n=222	*Duration:* 83-85 sessions (~30 weeks) *Mode:* aerobic/SE *Frequency:* 55-60 min 3 days/week *Intensity:* light-moderate intensity <70% age predicted HRmax/RPE 12-14 *Delivery mode:* Group *C:* Standard prenatal care, reported exercise levels once per trimester (by telephone)	GWG: I: +12.2 ± 3.7 C: +13.3 ± 4.1 p= .005	≥ 80
	Brik et al. (2019) Spain	NW/OW I: n=42 C: n=43	*Duration:* ~29 weeks *Mode:* aerobic/SE *Frequency:* 60 min 3 days/week *Intensity:* light-moderate intensity 55-60% HRmax *Delivery mode:* Group	GWG: I: +11.4 ± 4.2 C: +11.2 ± 6.4 NS	>70 (withdrawn from study if <70)

		C: Standard prenatal care, reported exercise levels (telephone interview)		
Dekker Nitert et al. (2015) Australia	OB I: n=19 C: n=16	*Duration:* ~22 weeks *Mode:* Individualised exercise plan meeting specified energy expenditure requirements based on personal preferences and ability *Frequency:* not stated *Intensity:* not stated *Delivery mode:* Group and individual *C:* Standard prenatal care	GWG: I: +7.87 ± 4.00 C: +8.3 ± 6.1 NS	NR
Garnæs et al. (2016) Norway	BMI >28 kg/m^2 I: n=38 C: n=36	*Duration:* ~24 weeks *Mode:* aerobic/SE *Frequency:* 60 min 3 days/week *Intensity:* <80% maximal capacity/RPE 12-15 *Delivery mode:* Group and individual *C:* Standard prenatal care	GWG: I: +10.5 C: +9.2 NS	50
Pelaez et al. (2019) Spain	NW/OW I: n=100 C: n=201	*Duration:* 70-78 sessions (≥24 weeks) *Mode:* aerobic/SE *Frequency:* 60-65 min 3 days/week *Intensity:* 65-70% age-predicted HRmax/RPE 12-14 *Delivery mode:* Group *C:* Standard prenatal care, general nutrition and physical activity counselling from healthcare professionals	GWG: I: +11.5 ± 3.5 C: +13.7 ± 4.1 p=0.01	96
Pawalia et al. (2017) India	NW/OW C: n=12 E: n=12 DE: n=12	*Duration:* ~24 weeks *Mode:* aerobic/SE *Frequency:* 60-90 min 2 days/week (supervised) 3 days/week (unsupervised) *Intensity:* RPE 12-14 *Delivery mode:* Group and individual *C:* Standard prenatal care	GWG: C: 7.58 ± 4.29 E: 5.75 ± 4.35 DE: 5.83 ± 3.68 NS	NR
Renault et al. (2014) Denmark	OB C: n=134 E: n=125	*Duration:* ~20 weeks *Mode:* walking *Frequency and intensity:* 10,000 steps per day	GWG (median/range):	NR

		DE: n=130	*Delivery mode:* Individual *C:* Standard prenatal care	C: 10.9 (-4.4 to 28.7) E: 9.4 (-3.4 to 28.2) DE: 8.6 (-9.6 to 34.1) p=.024	
	Ruiz et al. (2013) Spain	NW/OW/OB I: n=481 C: n=481	*Duration:* 85 sessions (~30 weeks) *Mode:* aerobic/SE *Frequency:* 50-55 min 3 days/week *Intensity:* <60% age-predicted HRmax/RPE 10-12 *Delivery mode:* Group *C:* Standard prenatal care, general nutrition and physical activity counselling	GWG: I: 11.9 ± 3.8 C: 13.2 ± 4.3 P<0.001	>97
	Simmons et al. (2017) United Kingdom, Ireland, Netherlands, Austria, Poland, Italy, Spain, Denmark, Belgium	OB C: n=79 D: n=76 E: n=74 DE: n=75	*Duration:* ≥15 weeks *Mode:* aerobic/SE and counselling *Frequency and intensity:* 30 minutes per day (progressing to 60 minutes if possible) moderate-vigorous activity on at least 5 days per week (preferably 7). *Delivery mode:* Individual *C:* Standard prenatal care	GWG: DE: 6.5 ± 3.8 E: 8.5 ± 5.0 D: 8.0 ± 4.7 C: 8.8 ± 4.7 p<0.05	NR
Postpartum studies	LeCheminant et al. (2014) USA	NW/OW/OB I: n=30 C: n=30	*Duration:* 18 weeks *Mode:* resistance training *Frequency:* 2 days/week *Intensity:* progressive through 18 weeks *Delivery mode:* Individual *C:* Flexibility training (active control group)	Pre- to post-intervention BMI: I: 25.0 ± 3.4 to 24.0 ± 3.5 C: 27.1 ± 3.9 to 26.3 ± 4.2 NS	~93
	Tripette et al. (2014) Japan	NW/OW I: n=17 C: n=17	*Duration:* 40 days *Mode:* active video games *Frequency:* 30 min daily *Intensity:* 10 MET·hr·wk^{-1} *Delivery mode:* Individual *C:* No intervention	WL: I: -2.2 ± 0.9 C: -0.5 ± 0.7 p<0.001	NR

Abbreviations: BMI, body mass index; C, control; D, diet; DE, diet and exercise; E, exercise; GWG, gestational weight gain; HRmax, maximum heart rate; I, intervention; NS, non-significant; NW, normal weight; NR, not reported; OB, obese; OW, overweight; RPE, rating of perceived exertion; SE, strengthening exercises; WL, weight loss

2.3.4.3 Methodological quality

There was considerable variability in methodological quality across the trials (Table 2.6). According to the criteria outlined in the Cochrane's tool for assessing risk of bias (Higgins and Green 2011), all trials were randomised. The method used for allocation concealment was clearly reported by Bacchi et al. (2018), Barakat et al. (2014), Barakat et al. (2019), Dekker Nitert et al. (2015), Garnæs et al. (2016), Renault et al. (2014), Ruiz et al. (2013) and Simmons et al. (2017). All studies, but one (Tripette et al. 2014), reported attrition rates and reasons for dropouts. Barakat et al. (2014), Bacchi et al. (2018) and LeCheminant et al. (2014) lost more than 20% of participants in the follow-up period and, therefore, the reporting bias (completeness of follow-up) was classed as inadequate. Brik et al. (2019) withdrew participants who were not attending ≥70% of exercise sessions and subsequently saw a 29.2% dropout rate; as such we also ranked the reporting bias as inadequate. Tripette et al. (2014) did not report attrition rates, therefore it was assumed that all of the participants finished the trial. Dekker Nitert et al. (2015) and Pawalia et al. (2017) presented the results of the first 35 and 36 women who completed larger RCTS, therefore dropout rates were not calculated. Three pregnancy studies completed follow-up assessments at six to eight weeks (Brik et al. 2019; Dekker Nitert et al. 2015) and two months postpartum (Pawalia et al. 2017). Most of the studies reported full data sets except for Bacchi et al. (2018) and Tripette et al. (2014). Both studies did not report maternal blood pressure data, and Tripette et al. (2014) did not report data for glycated haemoglobin and high-density lipoprotein cholesterol.

Table 2.6 Cochrane Collaboration's tool for assessing risk of bias (adapted from Higgins and Greene 2011)

	Selection bias			**Attrition/reporting bias**				
Study	**Randomised**	**Allocation concealment**	**Performance/detection bias Blinding**	**Follow-up**	**AR**	**R**	**DS**	**Bias Quality**
Bacchi et al.	A	A	A	C	Y	Y	F	Unclear
Barakat at al.	A	A	B	C	Y	Y	F	High
Barakat et al.	A	A	A	A	Y	Y	F	Unclear
Brik et al.	A	B	B	C	Y	Y	F	High
Dekker Nitert et al.	A	A	B	N/A	N/A	N/A	P	Unclear
Garnæs et al.	A	A	A	A	Y	Y	F	Unclear
Pelaez et al.	A	B	B	A	Y	Y	F	High
Pawalia et al.	A	B	B	N/A	N/A	N/A	F	High
Renault et al.	A	A	A	A	Y	Y	F	Unclear
Ruiz et al.	A	A	B	A	Y	Y	F	High
Simmons et al.	A	A	A	A	Y	Y	F	Unclear
LeCheminant et al.	A	B	A	C	Y	Y	F	High
Tripette et al.	A	B	B	A	N	N	P	High

Abbreviations: AR, attrition rates; DS, data set; F, full; N, not reported; N/A, not applicable; P, partial; R, reasons for drop-outs; Y, reported. NOTE: Overall bias quality calculated as follows; LOW- satisfies all of allocation concealment, blinding and follow-up, UNCLEAR- satisfies 2 out of 3, HIGH- satisfies 0/1 out of 3.

After attrition, group sample size ranged from 35 to 962 in the pregnancy studies and 34 (Tripette et al. 2014) to 60 (LeCheminant et al. 2014) in the postpartum trials. All included studies performed a power calculation (accepted level of power ranged between 79 to 95%) to determine sample size. Table 2.7 shows the recruitment success of each study against their *a priori* power calculation. Pawalia et al. (2017) presented the results of the first 36 women that were enrolled in a larger study and Dekker Nitert et al. (2015) presented the results of 35 women enrolled in the BAMBINO pilot RCT, therefore recruitment numbers are not presented here.

Only Garnæs et al. (2016) reported that they had used the CONSORT checklist (Table 2.8). Regarding the pregnancy studies, Bacchi et al. (2018) fulfilled 26 of 35 criteria (74%), Barakat et al. (2014) fulfilled 19 out of 35 criteria (54%), Barakat et al. (2019) fulfilled 24 out of 35 criteria (69%), Brik et al. (2019) fulfilled 24 out of 35 criteria (69%) and Dekker Nitert et al. (2015) fulfilled 16 out of 35 criteria (46%). Furthermore, Garnæs et al. (2016) fulfilled 34 out of 34 criteria (100%; adjusted for removal of 7b- stated as N/A), Pelaez et al. (2019) fulfilled 22 out of 35 criteria (63%), Pawalia et al. (2017) fulfilled 18 out of 35 criteria (51%), Renault et al. (2014) fulfilled 25 out of 35 criteria (71%), Ruiz et al. (2013) fulfilled 22 out of 35 criteria (63%) and Simmons et al. (2017) fulfilled 24 out of 35 criteria (69%). In the postpartum studies, LeCheminant et al. (2014) fulfilled 16 out of 35 criteria (46%) and Tripette et al. (2014) fulfilled 13 out of 35 criteria (37%). Only one trial reported important changes to the methods after trial commencement (item 3b), presented both absolute and relative effect sizes for binary outcomes (item 17b) and presented the results of subgroup and/or adjusted analyses (item 18) (Garnæs et al. 2016). Only Barakat et al. (2014) provided an explanation of any interim analysis and stopping guidelines.

Table 2.7 Recruitment success of included studies. Data presented as recruited/predicted based on sample size calculations.

	Recruitment Success	% Recruited of Initial Prediction
Bacchi et al (2018)	111/94	118.1
Barakat et al (2014)	251/266	94.3
Barakat et (2019)	520/340	152.9
Brik et al (2019)	120/90	133.3
Garnæs et al (2016)	91/150	60.7
LeCheminant et al (2014)	60/60	100.0
Pelaez et al (2019)	345/308	112.0
Renault et al (2014)	425/420	101.2
Ruiz et al (2013)	962/962	100.0
Simmons et al (2017)	436/440	99.1
Tripette et al (2014)	34/34	100.0

Table 2.8 CONSORT 2010 checklist of information to include when reporting a randomised controlled trial (adapted from Schulz et al., 2010)

Study	1a	1b	2a	2b	3a	3b	4a	4b	5	6a	7a	7b	8a	8b	9	10	11a	12a	12b	13a	13b	14a	14b	15	16	17a	17b	18	19	20	21	22	23	24	25
Bacchi	+	+	+	+	-	-	+	+	+	+	+	-	+	+	+	+	+	+	-	+	+	+	-	+	+	+	-	-	+	+	+	+	+	-	+
Barakat (2014)	-	+	+	+	-	-	+	+	+	-	+	+	+	+	+	-	-	+	-	+	+	-	-	+	+	-	-	-	-	-	+	+	+	-	-
Barakat (2019)	+	+	+	+	-	-	+	+	+	+	+	-	+	+	+	-	-	+	+	+	+	+	-	+	+	+	-	-	-	+	+	+	+	-	-
Brik	+	+	+	+	-	-	+	+	+	+	+	-	+	+	+	+	-	+	-	+	+	+	+	+	+	+	-	-	-	+	-	+	+	-	-
Dekker Nitert	-	+	+	+	-	-	+	-	-	-	-	-	+	+	-	-	-	+	-	+	+	-	-	+	+	+	-	-	+	+	-	+	+	-	+
Garnæs	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pelaez	+	+	+	+	-	-	+	+	+	+	+	-	+	-	-	-	-	+	+	+	+	+	-	+	+	-	-	-	+	+	+	+	+	-	+
Pawalia	+	+	+	+	-	-	+	+	+	+	-	-	-	-	-	-	-	+	-	+	-	+	-	+	+	-	-	-	-	+	+	+	+	+	-
Renault	+	+	+	+	-	-	+	+	+	+	+	-	+	+	+	+	-	+	+	+	+	+	-	+	+	-	-	-	-	+	+	+	+	-	+
Ruiz	+	+	+	+	-	-	+	+	+	+	+	-	+	-	-	-	-	+	+	+	+	+	-	+	+	+	-	-	+	+	-	+	+	-	+
Simmons	-	+	+	-	+	-	+	+	+	+	+	-	+	+	+	+	+	+	-	+	+	+	-	+	+	+	-	-	-	+	-	+	+	-	+
LeCheminant	-	-	+	+	-	-	+	+	+	-	+	-	+	-	-	-	-	+	+	+	+	-	-	+	+	-	-	-	+	+	+	+	-	-	-
Tripette	-	+	+	+	-	-	+	+	+	+	+	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	+	-	+	-	-	+

+=stated, -=not stated. NA, not applicable. **Items 3b and 18 were only applicable to Garnæs. Item 7b was only applicable to Barakat et al (2014).

2.3.5 Discussion

2.3.5.1 Main findings

The aim of the current systematic review was to update the review published by Elliott-Sale et al. in 2015 investigating the effects of an exercise intervention compared to routine care or another intervention on GWG in normal weight, overweight and obese women. Tables 2.9 and 2.10 show a comparison between the original (Elliott-sale et al., 2015) and updated reviews. In brief, in the original review, 67% of the interventions employed in the pregnancy studies were deemed successful (*i.e.* significant reductions in GWG when compared to a control or other intervention) and in the current update review, 46% of the interventions were deemed successful. For the postpartum studies, both the original and updated reviews showed that 50% of the interventions employed were deemed successful (*i.e.* greater postpartum weight loss when compared to a control or other comparison). There was large variation in the population characteristics and exercise modality, frequency, duration and intensity between the included studies in both reviews, which likely affected the magnitude and direction of the findings. In addition, the disparity in study design makes it difficult to compare interventions or draw conclusions. Therefore, it appears that further work is still required to identify the optimal design of antenatal and postnatal exercise interventions for weight management, although there is some evidence to suggest that exercise interventions can successfully moderate GWG and reduce PPWR.

In the current review, we identified 13 studies that fulfilled the inclusion criteria over a seven-year period compared with five studies identified in the original review over a 23-year period. It is possible that, because of recent evidence showing that exercise is safe during pregnancy without compromising the health of the baby (ACOG 2015; Bø et al. 2016; Bø et al. 2016a; da Silva et al. 2017), researchers have become more confident about designing and implementing exercise strategies during pregnancy. As such, it is evident that more work is now being completed that aims to understand the effects of exercise interventions on weight management during pregnancy.

Table 2.9 Main findings and comparisons between original and updated reviews in pregnancy studies. Data presented as n/total (% of total).

		Original review	Updated review
Weight status			
	NW	2/3 (66.6)	7/11 (63.6)
	OW	3/3 (100)	8/11 (72.7)
	OB	1/3 (33.3)	6/11 (54.5)
Intervention delivery			
	Group	1 (33.3)	5/11 (45.5)
	Individual	0 (0.0)	2/11 (18.2)
	Combined	2 (66.6)	3/11 (27.3)
Intervention success		2/3 (66.6)	5/11 (45.5)
Reported adherence		3/3 (100)	7/11 (63.6)
High attrition		1/3 (33.3)	3/9 (33.3)

Abbreviations: NW, normal weight; OW, overweight; OB, obese.

NOTES: Intervention success was defined as 'significantly less gestational weight gain in the intervention group compared to the control group'. High attrition was defined as '>20% dropouts'. In the updated review, attritions rates were reported as a score out of 9, rather than 11, as Dekker Nitert et al. (2015) and Pawalia et al. (2017) presented results of first 35 and 36 women, who completed larger RCTs.

Table 2.10 Main findings and comparisons between original and updated reviews in postpartum studies. Where appropriate, data presented as n/total (% of total).

		Original review	Updated review
Weight status			
	NW	1/2 (50.0)	2 (100)
	OW	2/2 (100)	2 (100)
	OB	1/2 (50.0)	1 (50.0)
Intervention delivery			
	Group	0/2 (0.0)	0/2 (0.0)
	Individual	2/2 (100)	2/2 (100)
	Combined	0/2 (0.0)	0/2 (0.0)
Intervention success		0/2 (0.0)	1/2 (50.0)
Reported adherence		1/2 (50.0)	1/2 (50.0)
High attrition		0/2 (0.0)	1/2 (50.0)

Abbreviations: NW, normal weight; OW, overweight; OB, obese.

NOTES: Intervention success regarded as significantly greater postpartum weight loss in the intervention group compared to the control group. High attrition defined as '>20% dropouts'. Tripette et al. (2014) did not report attrition rates, therefore it was assumed that all of the participants finished the trial.

2.3.5.2 Comparison with previous pregnancy findings

We compared our updated review results to the findings from other systematic reviews with a similar research aim. Chan et al. (2019) reviewed 29 studies, involving women of all BMI categories, and investigated the effect of physical activity interventions on various pregnancy-related issues. Fourteen of their included studies reported maternal weight or GWG as an outcome. Similar to the results of the current study whereby 45% of studies were successful in lowering GWG, Chan et al. (2019) showed that five studies (36%) showed significantly lower GWG among intervention participants when compared to standard antenatal care.

Muktabhant et al. (2015) performed an updated Cochrane Review from 2012 (Muktabhant et al. 2012), and showed that interventions focused on diet, exercise, or both reduced the risk of excessive GWG by ~20% in 24 studies including 7,096 pregnant participants. Interventions involving supervised or unsupervised exercise only, low glycaemic index diets, or combined diet and exercise all led to similar reductions in the proportion of women experiencing excessive GWG. Of the exercise interventions (*n* = 20) included in their review, the modality of exercise included supervised exercise, individualised exercise programs, pedometer or treadmill-focused and dance classes. In 2012, Muktabhant et al. concluded that there was insufficient evidence to recommend any exercise intervention for encouraging appropriate GWG. In 2015, the authors concluded that moderate-intensity exercise appears to be important in controlling weight during pregnancy, although most included studies were conducted in developed countries and it is unclear if their findings were applicable to developing countries. In the current study, the majority of included studies were also conducted in developed countries (9/11) and results agreed with the work of Muktabhant et al. (2015) that moderate intensity exercise was crucial in encouraging antenatal weight management. As such, investigations in developing countries are still required.

Finally, Campbell et al. (n.d.) reviewed 39 studies to determine the most effective types of lifestyle interventions for weight management during pregnancy. Their included studies were systematic reviews (*n* = 2), RCTs (*n* = 5), non-randomised (*n* = 5), case series (*n* = 2), observational (*n* = 14) and qualitative (*n* = 10) based. Campbell et al. (n.d.) concluded that the available evidence was weak, with a lack of agreement between studies employing similar interventions. As such, similar to the conclusion of Elliott-Sale et al., 2015, we are still not in a position to recommend the optimal exercise intervention design to deliver during pregnancy due to large disparities in the study design and findings of previous studies exploring the effects of exercise on GWG (Campbell et al. n.d.; Chan et al. 2019; Muktabhant et al. 2012, 2015; Sherifali et al. 2017).

2.3.5.3 Comparison with previous postpartum findings

In the postpartum period, results from the current study showed that one of two included studies (50%) reported significant reductions in weight when compared to a usual care group. Dodd et al. (2018) conducted a systematic review to evaluate the effect of dietary and/or physical activity interventions on weight loss. Of the 27 included studies, six delivered a physical activity intervention and compared it to no intervention or standard postnatal care. In agreement with results from the current study, only three studies (50%) reported a significant reduction in weight from pre- to post-intervention. Dodd et al. (2018) concluded that physical activity interventions were successful in reducing postpartum weight when compared to a usual care group, however the results must be interpreted with caution given that only three studies were included. Nascimento et al. (2014) drew similar conclusions stating that, across the 11 studies included, exercise interventions showed a significant effect on weight loss (-2.57kg) among postpartum women when compared to standard care. Nascimento et al. (2014) also noted that exercise programs including the use of objective measurements, such as heart rate monitors or pedometers, were effective in significantly reducing postpartum weight. Neither of the postpartum studies included in our review utilised objective measures of physical activity, however previous work by our group has also demonstrated that a weight loss intervention, including the use of an activity tracker, was effective in promoting post-intervention weight loss (Hanley et al., unpublished). From the studies included in our updated review and Dodd et al.'s (2018) and Nascimento et al.'s (2014) conclusions there exists large heterogeneity in study designs, and future work must identify and build on the successful components of intervention strategies (*e.g.* inclusion of objective measures of physical activity) delivered to postpartum women. In addition, maximising the effects of exercise on weight management during the postpartum period could contribute to the optimisation of both maternal and foetal health in subsequent pregnancies and beyond.

2.3.5.6 Comparison with eHealth technology-based exercise studies

In recent years, the emergence of mobile and other eHealth technologies has resulted in an increased use of these tools in health promotion and prevention-based interventions (Cocosila et al. 2009). Sherifali et al. (2017) conducted a review of the effectiveness of eHealth technologies on antenatal and postnatal weight management. Studies employing 12-week interventions, which were either (i) physical activity, (ii) nutrition, or (ii) both physical activity and nutrition based were included in the review. Results showed that eHealth technologies were beneficial in supporting only postpartum weight management. Sherifali et al. (2017) concluded, however, that more comprehensive research, piloting various eHealth approaches, is required to accurately determine the effect of eHealth interventions in women of childbearing age.

2.3.5.7 Summary of previous findings

During both pregnancy and the postpartum period, it is evident that further, well-controlled prospective studies are required to understand the optimal design of exercise interventions for both short- and long-term weight management. Results from various reviews, including our own, have shown inconsistent findings regarding the effects of exercise on the degree of GWG and postpartum weight loss. As such, it is crucial that future studies optimise the design of exercise interventions aimed at managing maternal weight.

2.3.5.8 Interpretation of current findings

In the studies aimed at managing GWG, there were large disparities in the exercise modality, frequency and duration, although moderate intensity exercise was consistently employed. The intensity of exercise seems crucial to encourage positive post-intervention outcomes. For example, Barakat et al. (2014) employed a light-moderate intensity program set at 55-60% of maximum heart rate and showed no difference in GWG between intervention and control groups following a 30-week program, but showed significant differences between groups in 2019 following an identical length program but set at ≤70% of maximum heart rate (Barakat et al. 2019), suggesting that antenatal exercise programs need to encourage sufficient and appropriate energy expenditure and positive resultant GWG outcomes. It also appears that exercise advice needs to be specific, as general advice, for example walking for a minimum of 30 minutes/day on four days of the week did not reduce GWG compared to standard care

(Pawalia et al. 2017). Renault et al. (2014) employed a walking program where women were set a specific target of 10,000 steps/day and experienced significantly less GWG than women in the control group. Renault et al. (2014) delivered the shortest intervention of all included pregnancy studies, demonstrating that specific, measurable goal orientated intervention approaches that encourage greater internal motivation may be most efficacious in delivering successful outcomes. All combined group and individual-based intervention approaches led to non-significant differences in GWG between intervention and control groups (Dekker Nitert et al. 2015; Garnæs et al. 2016; Pawalia et al. 2017), which could be due to the generalised, non-specific, nature of these intervention designs. For example, a group education session providing written leaflets on exercise and nutrition and the creation of exercise plans based on energy expenditure calculated from the Pregnancy Physical Activity Questionnaire (PPAQ) has demonstrated non-significant differences in post-intervention GWG outcomes between intervention and control groups (Dekker Nitert et al. 2015).

Only one of the two included studies was effective in reducing postpartum weight (Tripette et al. 2014), when comparing the intervention and control groups. Tripette et al. (2014) used a 40-day active video gaming protocol set at an intensity of 10 $MET \cdot hr \cdot wk^{-1}$, whilst LeCheminant et al. (2014) used an 18-week progressive resistance training protocol. Although Tripette et al. (2014) showed a significant reduction in postpartum weight in the intervention versus the control group over the 40-day period, the short-term nature of the intervention makes it difficult to draw conclusions on the long-term effect on weight management. In addition, the intervention involved a Nintendo Wii, meaning that women would need to purchase this equipment if they wished to continue the exercise programme beyond the trial period, which has a cost implication for the participants. Furthermore, whilst Tripette et al. (2014) showed positive correlations between total playing time and playing frequency with weight loss, they also showed higher injury rates in those individuals with longer playing times, which raises concerns regarding the supervision and instruction provided to participants. LeCheminant and colleagues (2014) supervised all exercise sessions during the first month of their 4-month intervention and at least one session per week in months two, three and four. Mild injuries were shown in five participants, which did not persist for longer than one to two weeks. Post-intervention, there was, however, no significant difference in postpartum weight loss between the intervention and active control participants suggesting that the intervention may not have been of a sufficient frequency or intensity to elicit significant responses. Although, the use of an active control group undoubtedly influenced the between group results, it must be noted that both groups experienced similar and significant reductions in bodyweight from pre- to post-intervention. LeCheminant et al. (2014) stated that they employed an active control group to minimise study withdrawals, but still experienced an overall dropout rate of 26.7%, which was more than any of the pregnancy studies. The observed high attrition rate may be explained by the finding that postpartum women identify a multitude of barriers when attempting to engage in a healthy lifestyle, including a lack of time and childcare (Saligeh et al. 2016), and, as such, may feel overwhelmed and unable to take part in exercise interventions during this time. The inclusion of formative work, specifically involving women in the design of exercise interventions, may allow the development of strategies to assist women in overcoming these barriers, and ultimately encourage better adherence and positive intervention outcomes. For example, Tripette et al. (2014) employed a home-based programme whereby participants could complete exercise sessions at a time suitable to them whilst attending to the needs and routine of the baby. As such, flexible home-based exercise programs, with necessary support, may be more appropriate for the postpartum population.

2.3.5.9 Quality of the findings

There was considerable variability in the methodological quality of included trials. The use of the CONSORT checklist (Schulz, Altman, & Moher, 2010) highlighted that, in the pregnancy studies, studies ranged from reporting 16 of the 35 included criteria (Dekker Nitert et al. 2015) to all criteria (Garnæs et al. 2016). Garnæs et al. (2016) were the only group to report the use of the CONSORT checklist. The postpartum studies covered 13 (Tripette et al. 2014) and 16 (LeCheminant et al. 2014) of the required criteria. The use of the Cochrane bias prevention framework (Higgins & Green, 2011) highlighted that seven of the 13 included studies were assessed as having a high risk of bias, six were assessed as unclear and none were assessed as low. All studies stated that trials were randomised however, only five studies described both blinding and allocation concealment strategies. As such, there still exists the need for future trials that conform to methodological quality (*e.g.*, CONSORT) and bias prevention frameworks (*e.g.*, Cochrane).

2.3.5.10 Strengths and limitations

Our review is comprehensive in its approach, as it covers women of all BMI status (underweight, normal weight, overweight, obese), during and following pregnancy, unlike previous reviews that have focused solely on either pregnancy or the postpartum period (Chan et al. 2019; Dodd et al. 2017; i-WIP Group 2017; Muktabhant et al. 2015; Nascimento et al. 2014). A recent review focused on both pregnancy and postpartum, however, only exercise interventions with an eHealth component were included (Sherifali et al. 2017). As we were providing an update to the review by Elliott-Sale et al. (2015) we focused exclusively on the effect of exercise on weight management. Whilst a sole focus upon the effects of exercise enables a highly stringent search and analysis strategy, it is limited to providing evidence for exercise interventions only, whilst some women will likely prefer to focus on both diet and physical activity to encourage weight management.

2.3.6 Conclusions

Exercise during pregnancy had mixed effects on GWG, as non-significant differences were observed between the intervention and control groups in 6 of the 11 included studies. In the postpartum period, exercise significantly enhanced weight loss in one of the two included studies. Owing to the conflicting results between the included studies, it is very difficult to conclude the most effective or appropriate exercise program during pregnancy and in the postpartum period. It appears, however, that antenatal and postnatal exercise interventions must be highly supported and deliver specific, goal-orientated advice. It is evident that attrition is an issue in postpartum studies involving exercise interventions, and, as such, future work must look to develop strategies to minimise participant withdrawal and effectively increase long-term physical activity levels.

In line with the conclusions made by Elliott-Sale et al. (2015), there still exists a need for future RCTs that comply with methodological quality (*e.g.,* CONSORT) and bias prevention frameworks (*e.g.,* Cochrane) to accurately determine efficacious approaches when designing and delivering exercise interventions to encourage weight management in pregnant and postpartum women. Moreover, given the discrepancies in the designs of previous studies, the optimal duration, frequency, and intensity of such exercise interventions still needs to be determined. The findings from this review should be incorporated into standard antenatal and postpartum care to encourage appropriate GWG and postpartum weight loss through physical activity.

2.3.7 Reference

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2.4 Modern dietary guidelines for healthy pregnancy; maximising maternal and foetal outcomes and limiting excessive gestational weight gain

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Contribution towards this review commenced prior to the official start of the PhD programme. SJH wrote sections 2.4.4, 2.4.5.5, and 2.4.5.6. In addition, SJH reviewed and edited the final manuscript.

2.4.1 Abstract

Maternal dietary habits influence maternal and foetal health, representing a pathway for intervention to maximise pregnancy outcomes. Advice on energy intake is provided on a trimester basis, with no additional calories required in the first trimester and an additional 340 kcal d^{-1} and 452 kcal d^{-1} needed for the second and third trimesters. Energy intake depends on pre-gravid BMI; underweight women are recommended an increase of 150, 200 and 300 kcal d^{-1} during the first, second and third trimester, normal weight women an increase of 0, 350 and 500 kcal d^{-1} and obese women an increase of 0, 450 and 350 kcal day^{-1}. The recommendations for carbohydrate and protein intake are 175 g d^{-1} and 0.88– 1.1 g kg BM d^{-1}, with no change to fat intake. The number of pre-gravid obese women is rising; therefore, we need to regulate weight in women of childbearing age and limit GWG to within the recommended ranges [overweight women 6.8–11.3 kg and obese women 5.0–9.1 kg]. This can be achieved using nutritional interventions, as dietary changes have been shown to help with gestational weight management. As pregnancy has been identified as a risk factor for the development of obesity, normal weight women should gain 11.5–16.0 kg during pregnancy. While some research has shown that dietary interventions help to regulate GWG and promote postpartum weight loss to

some extent, future research is needed to provide safe and effective guidelines to maximise these effects, while benefitting maternal and foetal health.

Keywords: Nutrition, health, weight

2.4.2 Highlights

- Only modest increments in dietary energy intake are required during pregnancy;
- Gestational weight gain needs to be limited to within the guidelines;
- Nutritional interventions have had some success in moderating gestational weight gain and postpartum weight retention

2.4.3 Introduction

Specific dietary practices are needed to sustain, and maximise, a healthy pregnancy and postpartum period, due to the physiological demands of gestation, childbirth and lactation. It is, therefore, important to not only consider pregnancy itself but also the time just before pregnancy (where possible) and the months following pregnancy. Gestational nutritional guidance has been the source of much debate and often controversy, as nutritional availability and advice has changed over time, ranging from periods of famine to an obesogenic environment. The Dutch Famine Birth Cohort Study (Roseboom et al., 2001) showed that maternal undernutrition, experienced during Second World War, resulted in chronic detriments in offspring health, such as cardiovascular disease, obesity, diabetes and pulmonary disease. In addition, nutritional deficiencies have been shown to result in preterm labour and intra-uterine growth retardation (Wen, Flood, Simpson, Rissel, & Baur, 2010). Conversely, eating for two is a contemporary idiom that relates to maternal overnutrition, which is also linked with many, adverse maternal and foetal health-related outcomes (Rasmussen & Yaktine, 2009; Stotland, Cheng, Hopkins, & Caughey, 2006). There is also evidence to suggest that pre-pregnancy BMI acts as a significant predictor of adverse health-related outcomes for both mother and baby (Schmitt, Nicholson, & Schmitt, 2007), indicating the importance of beginning pregnancy at a healthy weight. The maternal environment, and subsequent intra-uterine, foetal, environment, is an integral component of the Foetal Origins Hypothesis, which suggests that health trajectories are determined during gestation and that the effects of in utero programming are persistent and can remain dormant for years (Almond & Currie, 2011). The maternal supply of nutrients and oxygen has been shown to be crucial for foetal survival and adequate nutrition is necessary for healthy weight attainment (Rush, 2001). Therefore, the availability and constitution of the modern diet in relation to gestational health is extremely important and relevant. The physiological demands of pregnancy are associated with changes in dietary energy intake (DEI) and macro- and micronutrient composition (Forsum & Löf, 2007). The guidance on GWG, and thus DEI, changed noticeably in 2002 (Institute of Medicine, 2002) and was further modified in 2004 (Butte, Wong, Treuth, Ellis, & O'Brian Smith, 2004) to reflect pre-pregnancy BMI. Macronutrient intake is often complicated by contraindicated foods (Martin et al., 2016), which have been shown to vary between countries and over time. Often women are requested to supplement essential vitamins and minerals, which may otherwise be inadequate during pregnancy compared with prenatal intake (Haider & Bhutta, 2017). Alterations in diet, especially total energy, must be conveyed in an effective and timely fashion in order to maximise maternal and foetal outcomes. This is especially true for pre-gravid obese women or women with excessive GWG, as maternal obesity is associated with a myriad of adverse effects, such as gestational diabetes, preeclampsia and preterm delivery (Dutton, Borengasser, Gaudet, Barbour, & Keely, 2018). Therefore, the aim of this review was to (1) present the energy requirements and nutritional needs of pregnancy in relation to maternal and foetal outcomes and (2) to discuss dietary interventions for gestational weight management.

2.4.4 Energy requirements for healthy pregnancy

The need for energy and nutrients is increased slightly during pregnancy (Picciano, 2003). The body responds to the demands of pregnancy by becoming more energy efficient, through reduced habitual physical activity and lower metabolic rate, which means that only a small amount of additional energy is warranted (Ladipo, 2000). The IOM had previously recommended that all pregnant women should increase their DEI by 300 kcal d^{-1} (Institute of Medicine, 1990), although, since 2002, these recommendations have been revised to provide advice on energy intake on a trimester-by-trimester basis; no additional calories are required in the first trimester and an additional 340 kcal d^{-1} and 452 kcal d^{-1} are needed for the second and third trimesters (Institute of Medicine, 2002). Moreover, energy intake has been further quantified based on pre-gravid BMI; underweight women are recommended an increase of 150, 200 and 300 kcal d^{-1} during the first, second and third trimester, normal weight women an increase of 0, 350 and 500 kcal d^{-1} and obese women an increase of 0, 450 and 350 kcal d^{-1}

(Butte et al., 2004). Therefore, pregnant women need to adapt their DEI in line with their pre-pregnancy BMI, in order to avoid or limit excessive GWG. The disregard of these guidelines has led to pregnancy being identified as a risk factor for the development of obesity (Schmitt et al., 2007) and has contributed to the rising prevalence of maternal obesity. The application of these guidelines, especially the timing of delivery, is paramount to their success and, as such, we recommend that are provided in the pre-conception period or in the first trimester of pregnancy in order to be effective.

2.4.5 Nutritional needs for a healthy pregnancy

2.4.5.1 Determination of nutritional needs

The nutritional requirements of pregnancy are often difficult to define as changes in metabolism, renal function, urinary excretion and plasma volume make it difficult to determine the nutrient content of tissues and fluids. As a result of expanded plasma volume, nutrient concentrations in blood are often decreased, although total circulating quantities can be substantially increased.

2.4.5.2 Macronutrients

It is essential that the growing foetus receives sufficient amounts of energy in the form of glucose. 175 g d^{-1} of carbohydrate is recommended during pregnancy, which is an increase of 45 g d^{-1} compared to nonpregnant women (Brown, 2011). Diabetic pregnant women may be required to slightly reduce dietary carbohydrate intake, but non-diabetic pregnant women should not follow low-carbohydrate diets, as this puts the foetus at risk of poor growth rate, especially when a predominately low-glycaemic diet is followed (Clapp, 2002). Recent data have suggested that lower carbohydrate intake (229–429 g d^{-1}) during the second trimester of pregnancy is associated with less GWG than moderate carbohydrate intake (430–629 g d^{-1}) during the same period (8.03 kg compared with 10.00 kg on average; Pathirathna et al., 2017), although these carbohydrate intakes are higher than the 175 g d^{-1} recommended by Brown (2011). That said, those with a higher carbohydrate intake (630−829 g d^{-1}) during the second trimester of pregnancy also had a lower GWG than those with moderate carbohydrate intake (9.16 kg compared with 10.00 kg on average; Pathirathna et al., 2017). High-glycaemic diets, diets containing primarily high-glycaemic types of carbohydrate, have been shown to result in excessive GWG and delivery of larger babies and placentas (Clapp, 2002). These data suggest that: 1. part of the natural variation in birth weight can be attributed to maternal carbohydrate intake, which alters circulating maternal glucose and insulin levels; 2. consuming dietary carbohydrates that elevate postprandial glucose levels increase foeto-placental growth in the second and third trimester and 3. altering the source of maternal carbohydrate can be used to treat pregnancies at risk of abnormal foeto-placental growth.

During the second and third trimesters, an estimated 21 g d^{-1} of protein is deposited in maternal, foetal and placental tissues (Institute of Medicine, 2002). The Institute of Medicine (2002) recommends that women consume 71 g d^{-1} during pregnancy compared to a dietary reference intake (DRI) of 46 g d^{-1} in non-pregnant women, whilst other recommendations suggest that pregnant women consume between 75 and 100 g d^{-1} (Sforza Brewer & Brewer, 1985). The current Estimated Average Requirement (EAR) and Recommend Daily Allowances (RDA) for protein intake during pregnancy are calculated from factorial estimates as the nitrogen balance technique for determining protein requirement is too invasive and not appropriate for pregnant women. Elango and Ball (2016) calculated that 1.2 and 1.52 g kgBM d^{-1} of protein is needed during early (~16 wk) and late (~36 wk) stages of pregnancy, which is within the acceptable macronutrient distribution range but considerably higher than other current guidelines that recommend 0.88 (EAR) and 1.1 (RDA) g kg BM d^{-1} throughout pregnancy. Increased energy and protein intake have been shown to reduce the risk of preterm birth and stillbirth, low birthweight and small head circumference at birth (Ota, Hori, Mori, Tobe-Gai, & Farrar, 2015). Conversely, high-protein diets, containing more than 25% of total energy intake, have been shown to provide no additional benefit to either maternal or foetal health and may, in some cases, be detrimental (Lechtig et al., 1975; Rush, 1989).

The DRI for fat does not change as a result of pregnancy (20–35% of total calories), however, gestational diets should include essential fatty acids, choline, sterols, phospholipids and triglycerides to support foetal growth and development (Brown, 2011). In particular, essential fatty acid intake (13 g d^{-1} of omega 6 and 1.4 g d^{-1} of omega 3) is important for foetal brain development, especially visual and neural development (Innis, 2008). The early gestational fat deposition has been shown to contribute to the final trimester growth spurt and lactation, which highlights the need for appropriate fat intake throughout pregnancy (Crawford, Hassam, &

Stevens, 1981). There is a paucity of information regarding the role of maternal fat-soluble vitamins on infant brain development, however, future research is warranted to determine the impact of insufficient and excessive intake during pregnancy (Sánchez-Hernández et al., 2016). Maslova, Hansen, Strøm, Halldorsson, and Olsen (2014) used data from the Danish National Birth Cohort, to investigate the relationship between fat-soluble vitamins and their influence on immunity and inflammation. They showed that during pregnancy, maternal intake of vitamin A and E may defend against child allergic rhinitis, whilst vitamin K may increase the risk of childhood asthma.

2.4.5.3 Micronutrients

During pregnancy, the need for many micronutrients rises, due to an increased number of red blood cells and greater plasma volume and reduced levels of circulating nutrient-binding proteins and micronutrients (Ladipo, 2000). Despite this, some recent data have suggested that normal pregnancy can still be associated with a decline in the dietary intakes of energy and micronutrients (Goletzke, Buyken, Louie, Moses, & Brand-Miller, 2015). In their study of 566 women participating in the Pregnancy and Glycemic Index Outcomes Study, Goletzke et al. (2015) showed that energy intake decreased in the third trimester of pregnancy and that the dietary intake of folate, iron and fibre was insufficient to meet national recommendations. Gittelsohn, Thapa, and Landman (1997) have shown that inadequate intake, lack of prenatal nutritional knowledge, dietary taboos and restrictions associated with pregnancy and losses or malabsorption caused by pregnancy complications can result in micronutrient deficiencies. Such deficiencies can result in a number of adverse maternal and foetal health outcomes, such as anaemia, resulting in maternal death (Viteri, 1994) or foetal malformations, such as neural tube defects (Gernand, Schulze, Stewart, West Jr, & Christian, 2016).

2.4.5.4 Fruit and vegetables

Many essential nutrients, such as vitamins, fibre, folate and potassium, and bioactive substances, such as flavonoids and carotenoids, are found in fruit and vegetables, which are crucial for many aspects of health. Murphy, Stettler, Smith, and Reiss (2014) examined the link between infant birth weight or small for gestational age births and maternal fruit and vegetable consumption. Eleven studies were systematically reviewed, and their data included for meta-analysis. In highly developed countries, low vegetable intake was associated with small for gestational age birth and higher fruit and vegetable intake with increased birth weight. Two studies, in less developed countries, showed a relationship between increased birth weight and increased fruit or vegetable consumption. These authors concluded that, although the evidence for a protective effect of fruit and vegetable consumption on infant size was indefinite, a balanced diet including a selection of fruit and vegetables should be recommended during pregnancy. Venter, Brown, Maslin, and Palmer (2017) showed inconsistent findings from studies investigating the effects of maternal fruit and vegetable intake during pregnancy and lactation on allergic disease outcomes in offspring. They concluded that these contrary findings may be due to the poor definition of the term "fruit and vegetable intake" and due to the large variation in the nutritional content of the fruits and vegetables investigated and that future research is warranted that addresses these issues. In general, plant-based dietary practices, which include many types of fruit and vegetables, should be recommended during pregnancy in order to reduce the occurrence of excessive GWG (Brantsæteretal.,2014), GDM (Tryggvadottir, Medek, Birgisdottir, Geirsson, & Gunnarsdottir, 2016) and preeclampsia (Hillesund et al., 2014). In addition, they have been associated with several positive foetal outcomes, such as reduced risk of congenital anomalies (Vujkovic et al., 2009) and favourable foetal growth (Brantsæter et al., 2014).

2.4.5.5 Specific contraindicated foods and required supplementation

In order to avoid bacterial infections, such as salmonella and listeria, and maintain maternal and foetal health, NICE (NICE, 2017) recommend that pregnant women avoid unpasteurised milk, mould-ripened soft cheese, blue-veined cheese, pâté, uncooked or undercooked ready-prepared meals, raw or partially cooked eggs or food that may contain them and raw or partially cooked meats, especially poultry. In addition, they recommend 400 mcg of folic acid per day, in order to reduce the risk of neural tube defects. Vitamin D (10 mcg per day) is also advised for people at risk of vitamin D deficiency, such as women of African, African–Caribbean or South Asian origin, those with limited sun exposure, or those who cover their skin for cultural reasons. Vitamin A or routine iron supplementation is not recommended during pregnancy and foods containing high levels of vitamin A, such as liver or pate, should be avoided.

2.4.5.6 Vegetarians and vegans

Drake, Reddy, and Davies (1998) showed that there were no significant differences in pregnancy outcomes or energy intakes between ovolactovegetarians (no meat but dairy and eggs), fish plus ovolactovegetarians and omnivores, despite significant differences in micronutrients levels. Similarly, Piccoli et al. (2015) showed, in a systematic review of 22 studies, that neither vegan nor vegetarian diets resulted in an increased risk of negative pregnancy outcomes, with the exception of one study that showed a higher incidence of hypospadias. This review (Piccoli et al., 2015) also highlighted the contrasting evidence with regards to vegetarianism and birth weight, with five studies showing low birthweight and two studies showing high birthweight for children of vegetarian mothers. The authors concluded that the lack of randomised, controlled studies, alongside the heterogeneous and limited number of studies, prevented clear conclusions on the effects of a vegan and vegetarian diet in pregnant women on birth outcomes. Based on the evidence, it would appear that vegan and vegetarian diets can be regarded as safe if supplemented with micronutrients.

2.4.6 Dietary interventions for gestational weight management

2.4.6.1 Pre-gravid obesity

With 38% of the world's female population classified as obese (Ng et al., 2014), it is vital that the impact of obesity on maternal and foetal health is considered. Conception, pregnancy, labour and delivery, including surgery, are more difficult for obese women, therefore, helping these women to achieve a healthier, prenatal, weight should be part of our practice. Obesity during pregnancy can increase the risk of adverse health outcomes for both mother and baby. Studies show an increased risk of preeclampsia, GDM and hypertensive disorder in obese pregnant women, as well as increased incidence of macrosomia (Dutton et al., 2018). Pre-gravid obesity can also impair foetal monitoring, leading to the need for specialised equipment, issues with anaesthesia and a greater likelihood of miscarriage (Weindling, 2003). Maternal obesity is also linked with a host of long-term adverse health outcomes, such as postpartum weight retention, an unlikeness to breastfeed and childhood obesity (Fraser et al., 2011; Nehring, Schmoll, Beyerlein, Hauner, & Von Kries, 2011; Vesco et al., 2009). Recent data have also show an association between higher maternal BMI in late pregnancy and an increased risk of cardiovascular disease, type 2 diabetes and cancer in offspring (Eriksson, Sandboge, Salonen, Kajantie, & Osmond, 2014). As such, maternal obesity must be considered as a healthcare priority, due to its numerous and far-reaching effects. Moreover, the economic burden of maternal obesity must be considered as the associated costs of maternal overweight, GDM and macrosomia are substantial (Lenoir-Wijnkoop, van der Beek, Garssen, Nuijten, & Uauy, 2015).

In a sense, every routine or annual visit can be considered a pre-conception visit. While it is well known that obesity is associated with the risk of anovulation and infertility (Luke, 2017), *e.g.*, polycystic ovarian syndrome, in general, obese women have similar fecundity to those of normal BMI and are also as sexually active. There is, therefore, value in using each visit to help women achieve a healthier weight before becoming pregnant. Studies have shown that weight loss before conception is preferred and that weight loss between pregnancies also decreases the risk of stillbirth and infant mortality (Cnattingius & Villamor, 2016). There is an obvious need, therefore, for safe and effective interventions to regulate weight in women of childbearing age and while the perception of appropriate weight has changed, and more overweight women perceive themselves as normal, presenting the issue of obesity as a health issue, not an aesthetic one, is better.

Research from the last 10 years has shown that nutritional interventions can be effective as a means of facilitating weight management in pre-gravid obese women. Wolff, Legarth, Vangsgaard, Toubro, and Astrup (2008) showed that GWG was kept within the IOM guidelines by restricting energy intake and adopting the Danish Dietary Recommendations (fat intake: maximum 30%, protein intake 15–20% and carbohydrate intake 50–55%) in obese women. Daily energy intake, during the third trimester, was significantly different between the intervention and control groups (intervention: 1790 ± 539 kcal d^{-1}, control: 2282 ± 411 kcal d^{-1}), which resulted in significantly lower GWG in the intervention group (6.6 ± 5.5 kg vs. 13.3 ± 7.5 kg, mean difference 6.7 kg, 95% confidence interval (CI) of the difference: 2.6–10.8 kg, $p = 0.002$). Furthermore, no adverse effects on foetal growth were observed and fewer cases of pregnancy and birth complications (*e.g.,* GDM, pregnancy-induced hypertension) were detected in the intervention group compared to the control group.

Thornton, Smarkola, Kopacz, and Ishoof (2009) employed a balanced nutritional programme, with calorie restriction, to limit GWG in obese women. Participants were allocated into either a control or study group. Participants in the control group were counselled, on at least one occasion, regarding conventional prenatal nutrition guidelines. The study group received a more detailed dietary intake protocol, which was based on the advice given to patients with GDM. Participants were placed on an 18–24 kcal kgBM d^{-1} nutritionally balanced diet (40% carbohydrate, 30% protein and 30% fat) with no participant receiving a diet of less than 2000 kcal d^{-1}. Further to this, the study group were instructed to record all food and drink consumed each day in a diary, with the records reviewed at each prenatal visit. GWG was significantly lower in the study group compared to the control group (5.0 ± 6.8 kg vs. 14.09 ± 7.41 kg). Furthermore, no adverse perinatal outcomes were observed, thus confirming the benefits of a well-balanced, monitored, nutritional programme in regulating GWG in obese women. Future studies should, however, consider employing more robust measures than food diaries (*e.g.* weighed food intake) in order to accurately record and analyse DEI.

Bogaerts et al. (2013) showed that a lifestyle intervention significantly reduced GWG in obese women when compared to a routine care group. The intervention consisted of three groups; a control group, a brochure group and a lifestyle intervention group. Women in the brochure group were given written material on a healthy lifestyle, while the lifestyle intervention group received the same written material plus four 1.5–2 h antenatal lifestyle intervention sessions lead by a trained midwife, focusing on the relationship between energy intake and expenditure based on the active and healthy food pyramids for pregnant women. The control group consisted of routine antenatal care. GWG was significantly reduced in the brochure group (9.5 ± 6.8 kg) and the lifestyle intervention group (10.6 ± 7.0 kg) compared to the control group (13.5 ± 7.3 kg). Although the brochure group had greater overall reductions in GWG than the lifestyle intervention group, the percentage of women in each group that gained weight below the IOM guidelines (<5 kg) was similar (brochure 27.6% and lifestyle intervention 21.1%) and was significantly greater than the control group (6.3%).

McGivern et al. (2015) allocated obese women, with a BMI ≥ 35 kg m2 and in their second trimester, into either an intervention group (n = 89) or a non-intervention group (n = 89). The intervention consisted of seven healthy lifestyle sessions; the focus of the session was general and pregnancy-specific nutrition guidance, food safety and the use of the Eatwell plate model (Public Health England, 2016). The non-intervention group did not attend any sessions. As a result of the intervention, GWG was significantly reduced compared to the non-intervention group (intervention 4.5 ± 4.6 kg, non-intervention 10.3 ± 4.4 kg). While 21% of the participants in the intervention group either gained no weight or lost weight during pregnancy, there were no adverse maternal or foetal health outcomes observed.

These, and other, studies have shown that nutritional interventions can be used for gestational weight management in obese women. A systematic review of 13 studies on dietary interventions in overweight and obese pregnant women showed that GWG was reduced in nine studies (Flynn et al., 2016). They concluded that the development of clinical guidelines for dietary intervention in pre-gravid obese women is limited due to the large variation in the type of dietary interventions used.

2.4.6.2 Pregnancy as a risk factor for obesity

Pregnancy has been identified as risk factor for the development of obesity (Schmitt et al., 2007), as a result of excessive GWG and prolonged PPWR, which is often augmented by successive pregnancies that increase the risk of further weight gain and subsequent retention. The IOM advises that underweight (pre-pregnancy BMI < 18.5 kg m^2) and normal weight (pre-pregnancy BMI 18.5–24.9 kg m^2) women gain 12.5–18.0 kg and 11.5–16.0 kg during pregnancy in order to avoid excessive GWG (Rasmussen & Yaktine, 2009). Energy intake during pregnancy is essential for supporting foetal growth and development (Barker, 1990), although the IOM has reported that many women are exceeding GWG guidelines (Institute of Medicine, 2009), often citing poor nutrition as a major contributing factor (Samura et al., 2016). Among American women, 47.5% exceeded IOM guidelines for GWG (5% and 37.6% of underweight and normal weight women; Deputy, Sharma, Kim, & Hinkle, 2015) and in the UK, 5% of women, have, at one stage in their pregnancy, attained a BMI of ≥ 35 kg m2 (National Obesity Observatory, 2014). These statistics clearly highlight the need to avoid excessive weight gain during pregnancy, which is retained beyond pregnancy, and the need for effective interventions to achieve this.

Luo, Dong, and Zhou (2014) showed that in normal weight Chinese women, individualised nutritional management resulted in significantly less GWG when compared to a control group receiving routine antenatal care (7.58 ± 1.59 vs. 12.57 ± 4.62 kg. p = .000). The individualised nutrition plans focussed on the inclusion of whole grains, fruits, beans and vegetables, combined with extensive obstetric care. This intervention may, however, be difficult to extrapolate to all normal weight populations, due to the highly specific Chinese diet.

In a similar approach to Luo et al. (2014), Walsh, McGowan, Mahony, Foley, and McAuliffe (2012) examined the effects of a low-glycaemic index (GI) diet on Irish women during their second pregnancy. Eating a high GI diet has been shown to increase the risk of developing maternal diabetes, macrosomia and excessive GWG, while a low GI diet is associated with normal foetal growth and normal maternal weight gain (Clapp, 2002; Moses et al., 2006). Eight hundred pregnant women were randomised into either an intervention group (n = 394) or control group (n = 406). Women in the intervention group attended a dietary education session at 15.7 ± 3.0 week's gestation. The session focused on healthy eating, following the food pyramid, and on encouraging the inclusion of as many low GI foods as possible; *i.e.,* exchanging high GI foods for low GI alternatives. Written material to promote the inclusion of low GI foods into their daily eucaloric diet was also issued. The control group received routine antenatal care. At 40 weeks gestation, the intervention group showed significantly less GWG when compared with the control group (12.2 ± 4.4 kg vs. 13.7 ± 4.9 kg, p = .017). This novel study showed that a low GI diet can result in positive maternal outcomes, namely reduced GWG when compared to routine antenatal care. This study employed a eucaloric approach, therefore negating any issues with undernutrition.

Asbee et al. (2009) demonstrated that in women, with varying pre-pregnancy BMI's, dietary and lifestyle counselling can limit GWG. The study group received counselling on a healthy diet (40% carbohydrate, 30% protein and 30% fat) while the control group received routine antenatal care throughout pregnancy. Participants also received lifestyle counselling, wherein they were advised on appropriate weight gain during pregnancy based on the IOM guidelines and were instructed to perform physical activity throughout pregnancy, although physical activity levels were not monitored. The intervention resulted in significant reductions in GWG when compared with the control group (28.7 ± 12.5 lb vs. 35.6 ± 15.5 lb), however did not manage to increase the number of women who gained weight within the IOM guidelines (intervention: 61.4%, control: 48.8%, $p = .21$).

2.4.7 Conclusion

In order to sustain the physiological demands of pregnancy a balanced diet should be consumed; wherein additional calories are consumed in the second and third trimesters (340 kcal d^{-1} and 452 kcal d^{-1}). Additional caloric consumption should be based on pre-pregnancy BMI and adjusted accordingly; meaning an increase of 150, 200 and 300 kcal d^{-1}, 0, 350 and 500 kcal d^{-1} and 0, 450 and 350 kcal d^{-1} per trimester for underweight, normal weight and obese women. These dietary changes should include an increase in carbohydrate and protein, but not fat intake, in order to maximise maternal and foetal health outcomes. The rising prevalence of pre-gravid obesity, coupled with excessive GWG, means that contemporary, effective nutritional guidelines for weight management and maternal and foetal health are imperative. Appropriate GWG should be achieved through regulating maternal nutritional practices and keeping within the IOM guidelines for GWG, especially in relation to pre-pregnancy BMI and on a trimester-by-trimester basis. Similarly, the additional energy required to sustain a healthy viable pregnancy changes during each trimester and as a result of pre-pregnancy BMI. In the case of pre-gravid obesity, calorie guidance appears to be an effective intervention for weight management. Any nutritional intervention or dietary practice employed during pregnancy must ensure that pregnancy does not become a significant risk factor for the development of obesity in normal weight women.

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2.5 Conclusions

This literature review explored the impact of excessive GWG on short and long-term maternal and offspring outcomes across multiple pregnancies and in later life and assessed the effects of lifestyle interventions on weight management and indices of health in pregnant and postpartum women.

The first review (section 2.2), exploring the effects of positive energy balance, resultant excessive GWG and PPWR on maternal and child health during pregnancy and in subsequent pregnancies, showed that the optimal nutrition-based pregnancy and postpartum intervention remains unknown. This uncertainty is primarily due to several methodological issues, such as: the use of self-report instruments for dietary assessment; issues with external validity; and lack of long-term follow-ups. Furthermore, nutritional interventions aimed at limiting GWG are delivered to all pregnant women irrespective of the number of previous gestations. It would be reasonable to suggest that women encounter barriers to a healthy lifestyle in varying intensities according to the number and age of the children they must care for; therefore, future work must consider this and also include long-term follow up periods to allow us to understand the effects of lifestyle interventions on health in subsequent pregnancies and later life.

The updated systematic review (section 2.3), exploring exercise interventions in pregnancy and up to one-year postpartum, showed that exercise has mixed effects on GWG and PPWR, as six of the 11 pregnancy studies and one of two postpartum studies included in the review displayed non-significant results between the intervention and control groups. It is also extremely difficult to recommend the optimal design of exercise interventions given that; for example, some studies employ group-based approaches, some employ individual approaches and others employ a combined group and individual approach. There are also large discrepancies in the intensity and frequency of antenatal exercise interventions, with the frequency ranging from two days per week to daily exercise engagement, and the intensity ranging from light-moderate on the RPE scale to 80% of maximal capacity. The delivery of specific and goal-orientated intervention approaches does however appear to have an efficacious effect on weight management in the antenatal and postnatal periods. Therefore, future work must look to incorporate goal-focused and individualised approaches to increase the effectiveness of exercise interventions aimed at encouraging appropriate GWG and postpartum weight loss in women of all BMI status.

The third review, (section 2.4) developing up-to-date antenatal dietary energy intake guidelines and exploring dietary interventions for gestational weight management, showed that, in order to achieve GWG within IOM recommended ranges (Institute of Medicine (US) and National Research Council (US) Committee to Reexamine IOM Pregnancy Weight Guidelines, 2009), only modest increments in dietary energy intake are required in the second and third trimesters based on pre-gravid BMI. Nutritional interventions containing aspects of calorie counting appear to be effective strategies for obese women to encourage appropriate GWG, and crucially, all interventions delivered to normal weight women must ensure, through dietary counselling, that pregnancy does not become a significant risk factor for the development of obesity.

In order to address the gaps in knowledge (specifically, efficacious intervention design strategies to encourage weight management in the postpartum period in overweight and obese women) and the methodological flaws (namely lack of co-researcher and end-user design, intervention follow-ups and issues with external validity) highlighted by the three review papers included in this literature review, the following studies were conducted:

1) Experiences of Exercise, Healthy Eating and Quality of Life During and Following Pregnancy in Overweight and Obese Postpartum Women (reported in Chapter 3).
2) Patient and Public Involvement: Using Formative Work to Underpin Future Lifestyle Interventions (reported in Chapter 4).
3) The Effects of Exercise and Dietary Interventions in Overweight and Obese Postpartum Women on Weight Management and Health (reported in Chapter 5).
4) An Exploration into the Thoughts and Opinions of Postpartum Women Following Engagement in a Lifestyle Intervention: Exit Questionnaires (reported in Chapter 6).

Chapter 3: Experiences of Exercise, Healthy Eating and Quality of Life During and Following Pregnancy in Overweight and Obese Postpartum Women

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This paper was submitted to the *Journal of Midwifery & Women's Health* in February 2021. Please note that this Chapter is presented in the journals format, but have been numbered [sub-heading, Tables and Figures] in line with the thesis.

3.1 Abstract

Objective- This retrospective study explored the experiences of women with overweight or obesity regarding physical activity, diet and quality of life leading up to, during, and following pregnancy.

Design- A qualitative descriptive design was adopted, whereby data collected through semi-structured interviews were analysed using thematic analysis. Throughout the interviews, individuals were asked to describe their barriers to a healthy lifestyle during and following pregnancy.

Setting- Clifton campus, Nottingham Trent University, UK.

Participants- Ten women (34.5 ± 5.2 years old, BMI 30.4 ± 3.5 $kg \cdot m^{-2}$) who were between 12 and 52 weeks postpartum participated.

Measurements and findings- A range of themes were identified when discussing barriers to exercise and healthy eating during and following pregnancy, which included tiredness; support; convenience; medical complications; cost; cravings and nausea. *Tiredness*, especially in the third trimester of pregnancy, and a lack of *support* at home, was often cited as preventing engagement in exercise and healthy eating practices. A lack of *convenience* when attending exercise classes, *medical complications* following the birth and the *cost* of attending pregnancy-specific classes were identified as barriers to exercise engagement. *Cravings* and *nausea* were identified as barriers to healthy eating during pregnancy. Quality of life was positively associated with exercise and healthy eating, whilst a lack of sleep, loneliness and a loss of freedom since the baby had arrived negatively influenced quality of life.

Key conclusions- It is evident that overweight and obese postpartum women experience many barriers when attempting to engage in a healthy lifestyle during and following pregnancy.

Implications for practice- These findings can be used to inform the design and delivery of future lifestyle interventions in this population.

Keywords: **Pregnancy, postpartum, physical activity, diet, lifestyle intervention**

3.2 Introduction

Over half of the women of childbearing age in most developed countries are either overweight (BMI 25-29.9 kg·m^2) or obese (> 30 kg·m^2) (NHS Digital 2017). Pregnancy can result in additional increases in BMI; for example, Johnson et al. (2013) showed that 73% (from a sample of 8,293) of women gained weight in excess of the IOM guidelines (Institute of Medicine (US) and National Research Council (US) Committee to Reexamine IOM Pregnancy Weight Guidelines 2009). In comparison to normal weight women, women who are overweight or obese are more likely to experience excessive GWG (Deputy et al. 2015), which can result in adverse outcomes, including LGA offspring, hypertensive disorders and a higher risk of caesarean section (Johnson et al. 2013). The postpartum period is often defined as the 12 months after childbirth, during which time the weight gained during pregnancy should be lost. Women often experience weight retention long beyond the postpartum period and enter subsequent pregnancies with higher BMI's (Kirkegaard et al. 2015).

Despite increasing evidence for the benefits of a healthy lifestyle during and following pregnancy on positive short- and long-term birth outcomes (Aviram et al. 2011; Barker et al. 1993; Zhang and Ning, 2011), physical activity levels tend to decline during pregnancy (Brown et al. 2009; Engberg et al. 2012) and often remain reduced long into the postpartum period (Berge et al. 2011; Fell et al. 2009; Gaston and Cramp, 2011; Pereira et al. 2007). Diet quality, referred to as the balance between the consumption of healthy (e.g. wholegrains, fruits, vegetables) and unhealthy foods (e.g. sugar, sodium, saturated fats; Guenther et al. 2013; World Health Organisation 2018) also worsens during pregnancy, especially in overweight and obese women, and is maintained at this reduced level following childbirth (Moran et al. 2013). Perceived QoL can also decrease following childbirth (Martínez-Galiano et al. 2019), which may be associated with reduced physical activity and diet quality during this time in comparison to before and during pregnancy.

Previous research investigating the barriers to physical activity engagement during pregnancy have revealed a combination of intrapersonal and interpersonal barriers (Coll et al. 2017). Intrapersonal barriers, including tiredness, fatigue, physical pain, nausea and body shape changes; and interpersonal barriers such as a lack of knowledge about how to exercise safely whilst pregnant and a lack of guidance from healthcare professionals on the benefits of physical activity have all been reported as barriers to exercise engagement during pregnancy (Coll et al. 2017). There are a number of shared and unique barriers to physical activity engagement in the postnatal period, which include a lack of time, lack of social support, fatigue, childcare responsibilities, illness and housework (Bellows-Riecken and Rhodes, 2008; Albright et al. 2015; Saligheh et al. 2016; Cramp and Bray, 2010).

Pregnancy symptoms such as nausea and vomiting, low socioeconomic status, maternal depression and community factors such as the unavailability of healthy foods, have been shown to limit diet quality in pregnant women (Finch, 2003; Hurley et al. 2005; Pepper and Craig Roberts, 2006; Powell et al. 2007). Few studies have focused on understanding specific barriers to healthy eating in postpartum women. Recent work aimed at understanding the healthy eating experiences of low-income breastfeeding mothers showed that women invested more time into the care of their children and did not view healthy eating as a priority (MacMillan Uribe and Olson, 2018). Women perceived they were too busy to prepare nutritious meals and viewed shopping for fresh ingredients as a burden on their daily routines, despite understanding that healthy eating positively affected their overall health (MacMillan Uribe and Olson, 2018).

Although the knowledge base surrounding potential barriers to following a healthy lifestyle during and following pregnancy has expanded in recent years, there remains a dearth of information related to barriers to participation in overweight and obese participants. For example, Coll et al. (2017) conducted a review of studies exploring perceived barriers to leisure-time physical activity during pregnancy and, of the 14 qualitative studies included published between 1986 and 2016, only three reported findings related exclusively to overweight and obese women and only one study was completed in the United Kingdom over 10 years ago (Weir et al., 2010). A number of studies have been completed in women of mixed BMI status (normal weight, overweight and obese) (*e.g.* MacMillan Uribe and Olson, 2018; Saligheh et al., 2016; Albright et al., 2015; Evenson et al., 2009), however these results do not indicate where, and if, differences exist regarding the barriers experienced by overweight and obese women compared to normal weight women. It may be that overweight and obese women experience unique challenges, which are weight-related, that limit their ability to adopt mainstream lifestyle interventions. Work is urgently required to understand these women's experiences during and following pregnancy, especially as several postpartum lifestyle interventions in overweight and obese populations have proven ineffective in promoting behaviour change (Heppner et al. 2011; Skouteris et al. 2012; Vesco et al. 2012) and significantly reducing BMI (Østbye et al. 2009; Walker et al. 2012). Pregnancy and the postpartum period have both been identified as 'teachable moments' whereby women are motivated to adopt risk-reducing health behaviours (*e.g.* healthy eating, exercise engagement) to benefit both their own and their baby's health (Dinsdale, Branch, Cook, & Shucksmith, 2016; Phelan, 2010). Therefore, in order to better capitalise on this period of time in women's lives and increase the successfulness of antenatal and postnatal lifestyle interventions, a comprehensive understanding of the barriers preventing overweight and obese women from maintaining a healthy lifestyle during and following pregnancy is crucial in order to guide the design and delivery of future lifestyle interventions in the United Kingdom, with the aim of promoting appropriate GWG, postpartum weight loss, and long-term maternal and offspring health. Thus, the aim of this study was to examine the experiences of overweight and obese women regarding physical activity, diet and QoL leading up to, during, and following pregnancy. The results can be used to inform the design and delivery of lifestyle interventions in the same population.

3.3 Methods

This study sought to gain an understanding of participants' experiences before, during and following pregnancy, through rich descriptions. Furthermore, the study aimed to generate results that would be available to practitioners to underline practical applications and to inform the design of future intervention-based research studies. As such, the Qualitative Descriptive approach described by Sandelowski (2000) was adopted, underpinned by an interpretivist perspective. The research team explored individuals' unique experiences leading up to, during and following pregnancy whilst recognising that experiences are socially constructed and based on individual interpretation.

3.3.1 Participants

Ten participants (34.5 ± 5.2 years, BMI 30.4 ± 3.5 kg·m^{-2}) were recruited through social media and community platforms. Data saturation was suspected following the analysis of eight interviews. As such, in line with recommendations (Forsberg, Backman, & Moller, 2000; Jassim & Whitford, 2014), two further interviews were conducted to confirm the emergence of no new themes (Given, 2016). Data saturation is regarded as an essential methodological element of qualitative research (Saunders et al., 2018), and is deemed the 'the most frequently touted guarantee of qualitative rigor offered by authors' (Morse, 2015). Furthermore, Guest, Bunce, and Johnson (2006) refer to saturation as 'the gold standard by which purposive sample sizes are determined in health science research' and many authors refer to it as a 'rule' (Denny, 2009; Sparkes, Duarte, Raphael, Denny, & Ashford, 2012) or an 'edict' (Morse, 1995) of qualitative work. Potential participants were purposefully sampled to ensure in-depth accounts and thus sufficient information to address the research questions (Patton, 2002). Participants were invited to take part if they were primiparous, had a singleton pregnancy and were between 12 weeks and 52 weeks postpartum. Given that women attend a six to eight week check with a general practitioner to determine if normal physical activity can be resumed following childbirth, twelve weeks postpartum was deemed sufficient time to allow individuals the opportunity to experience and identify postpartum barriers to a healthy lifestyle and to allow sufficient recovery time from childbirth, especially in those who had had a caesarean section. At the time of study participation, participants also had to have a BMI of > 25 kg·m^{-2}.

3.3.2 Procedure

Following ethical approval, study advertisements and posters were placed on notice boards in the community and on various social media sites (*e.g.*, Facebook, Twitter, Mums Net). Potential participants contacted the research team directly to indicate their interest and were provided with more detailed information regarding the study. Several participants identified other potential individuals who fulfilled the inclusion criteria and passed on the study details to them such that communication with the research team was instigated by the potential participant to ensure that they did not feel that they had to participate or felt compelled to reply in a certain manner.

3.3.3 Data Collection

Participants were provided with detailed verbal and written explanations of the study and informed consent was obtained. Interviews were broadly structured as a life-history interview, such that participants were encouraged to share stories from throughout their life and, where possible, placed these stories within specific historical life stages (*e.g.*, childhood, stage of pregnancy) (Smith and Sparkes, 2017). This approach allowed participants to take control of the interviews and to position their experiences along the time course of their pregnancies and into the postpartum period.

Prior to conducting any interviews with the intended participants, an interview guide was piloted, which allowed the interviewer to become familiar with the interview questions. Following the pilot interview, the interview guide was revised such that introductory questions were included to address each of three main topics: physical activity, nutrition and opinions on the design of lifestyle interventions. For example, on the topic of physical activity the first question was, “When I say the words “physical activity” what comes to mind?” (Appendix 3C). Prior to the formal interview, time was spent building rapport with the participants and the layout of the interview guide was slightly altered to gain a clearer understanding of overall, childhood, pregnancy and postpartum experiences when discussing each topic.

Interviews were conducted in a private room on a university campus or at the participant’s home. Participants were given the choice of where they wanted the interview to take place, which may have enabled them to feel more comfortable to speak openly and empowered in their interaction with the interviewer (Elwood and Martin, 2000). Data collection for the study was completed between February and March 2018. The interview guide contained questions about the delivery, views and experiences of physical activity and diet during childhood, stages of pregnancy and postpartum. Interviews ranged in length from 28 to 45 minutes (36 min 17 secs ± 5 mins 18 secs) excluding the time spent building rapport with participants prior to commencing the recorded interviews and were transcribed verbatim.

3.3.4 Data Analysis

Thematic analysis, based on the approach adopted by Braun and Clarke (Braun and Clarke, 2006; Braun et al. 2017) was completed. Familiarisation of the data, or transcripts, occurred through the process of immersion, which involved repeatedly reading the data and identifying any emerging specific patterns and meanings in the data. Following this, a detailed reading of each transcribed interview was carried out, highlighting potentially meaningful or interesting ideas and arranging them under different headings (termed codes; for example, 'reduced physical activity during pregnancy', 'lack of dietary restraint', 'long-term weight issues'). Next, themes were developed which were interpretative and focused on aspects of the participants' experiences, for instance of diet or physical activity or QoL. Coded data were arranged under developed themes and relationships between the codes, themes and different theme levels (*e.g.*, main overarching themes and sub-themes) were also developed. During and following the process of thematic analysis, themes were further refined to reflect all appropriate codes. Such refinement occurred initially at an individual researcher level and then independently by another member of the research team, and where necessary, any conflicts were discussed and resolved.

3.3.5 Methodological Rigour

Smith and Sparkes (2017) have suggested that the quality of qualitative research should be judged using a relativist, rather than a criterion, approach. Consequently, the nine proposals by Smith and Caddick (2012) that were applicable to the current study were employed; namely *substantive contribution, impact, comprehensiveness of evidence, coherence, catalytic and tactical authenticity, resonate and credibility and transparency*. These criteria are flexible and open to reinterpretation and encourage readers to draw upon their own conclusions.

3.4 Results

Throughout the interviews, participants were asked to recount their experiences; in the years prior to, during and following pregnancy. Themes were organised and presented in line with the overall study aim to understand the barriers to exercise, healthy nutrition and QoL during pregnancy and in the postpartum period in overweight and obese postpartum women. Tables 3.1 and 3.2 display the results regarding perceived barriers to exercise and nutrition during pregnancy whilst perceived barriers in the postpartum period are presented in Tables 3.3 and 3.4. Table 3.5 displays findings regarding QoL. These results can be used to inform the design of exercise and dietary interventions in postpartum women with overweight or obesity.

Table 3.1 Perceived barriers to exercise during pregnancy.

Exercise Barriers (Pregnancy)		
Theme	***Sub-theme***	***Example Code***
Tiredness	Too tired	*In the first trimester it's so tiring, like you're so exhausted for no apparent reason you just feel exhausted, so you have literally zero energy. (P05)*
Support	Little advice	*The only advice I've got is stuff that, well I know myself, or look on the internet and that sort of thing. (P03)*
	Discouraged engagement	*Stopped running in my second trimester because somebody made a comment to my husband… Should she be running? And I don't know it frightened me. (P02)*
Work	Work prevents class attendance	*Swimming times for adults tend to be during the day… and when you work full time you can't really get there. (P04)*
Physical	Bigger and more cumbersome	*Went swimming once, we basically just floated around because we were just two big whales together. We were huge. (P05)*
	Nausea	*Quite nauseous and probably only managed to go to the gym maybe once a week until probably week sixteen. (P01)*
	Need toilet more often	*And then basically I needed the toilet every time I, like running out of the class ever ten minutes, like oh god… So I just did pilates and a bit of yoga at home, that sort of stuff. (P01)*
Convenience	Time of day [don't like evenings]	*You know I was in work by 7.30am leaving governor's meetings at 6.30 at night. The last thing you want to do is go to the gym…Whereas before, I probably could have*

		done it. But all I wanted to do was go home. (P04)
	Unable to locate classes	*There was just nothing really available… couldn't find anything that got me going either. (P08)*
Health and safety	Fear of miscarriage	*I think I was probably about five weeks pregnant or something when I found out so not that far gone, and then I waited, I basically stopped going to the gym at that point myself because I was really conscious about not exercising too much because I really didn't want to lose the baby. (P05)*
	Hockey contraindicated during pregnancy	*So the physical activity I'd done before I was pregnant, I couldn't carry on with. I mean you can play hockey when you're pregnant, but it's not a good idea to. (P04)*
Time	Lack of time	*So, what do you think stopped you from picking up anything new when you weren't able to play hockey and cricket anymore?* *Possibly time a bit. (P09)*
Cost	Too expensive	*Paying for a gym membership is expensive and a lot of them tie you in. (P09)*

Table 3.2 Perceived barriers to healthy nutrition during pregnancy.

Nutrition Barriers (Pregnancy)		
Theme	***Sub-theme***	***Example Code***
Cravings	Crave (rubbish)	*So, during the first trimester you do just crave absolute rubbish which I found quite surprising because you'd think that your body would want to have stuff that's really nutritious and good for you. (P01)*
	"Needed" salt	*Just those first couple of weeks I just needed salt and crisps and paninis basically and hash browns.(P01)*
Nausea	Morning sickness [better when eating]	*I had really bad morning sickness, but it was sickness all the time and the only thing that would stop it was eating. So I just ate. (P02)*
	Repulsed by meat & other foods	*The sight of meat repulsed me and I was, I was in Aldi, picked up some like turkey mince and just started retching and had to run out of the shop. (P01)*
Restraint	Not drinking, eating more	*Because I wasn't going out on the weekends and drinking wine, I was thinking actually, that's loads of calories saved, it probably doesn't matter if I have a bit of a treat. (P03)*
	Having treats, no restraint	*Before I had a little bit more self-restraint, but when I was pregnant I was like oh it doesn't matter… I'm probably going to get a bit fat anyway. (P01)*
Tiredness	Feel rubbish, eat crap	*When I got tired would be grabbing something on the way home. (P04)*

Table 3.3 Perceived barriers to exercise in the postpartum period.

Exercise Barriers (Postpartum)		
Theme	***Sub-theme***	***Example Code***
Medical Complications	Episotomy	*She had to be delivered by forceps because her heart rate was dropping so they decided they needed to get her out pretty quick and obviously as they went to cut me to get the forceps in, because they're pretty big, don't ever look at them. They cut me to my back passage unfortunately, so I had to go straight into surgery to be stitched back together afterwards. (P04)*
	Heavy bleeding	*Experienced quite heavy bleeding during that time as well, so that's particularly uncomfortable. (P01)*
	Pelvic pressure	*Very, very conscious… make sure I go for a wee beforehand. (P02)*
	Reduced strength	*Because usually, I use my stomach muscles you know, to like get up and I just couldn't do it, so he had to come over and take the bar off and I had to sort of roll off the bench. (P01)*
	Unfused stomach	*Checking to see whether your muscles are fused, the doctor doesn't check that. They just ask you questions. (P01)*
	Back pain/pressure	*Found it [at home exercise program] was putting too much pressure on my back. (P01)*
	Body not ready/too heavy for return to exercise and sport	*Because there's no way after a year my body is ready to go back to playing hockey. (P04)*
	Recovery from c-section	*It took ages for my C-section scar to heal and yes a lot longer than other friends of mine seem to… I think they said I could exercise*

		after twelve weeks but I took ten weeks before I could walk properly again, so I didn't do any exercise for ages. (P10)
Convenience	Hard to get to classes	*The one (exercise class) at the hospital it's a faff getting to anyway when you've got an appointment in there. (P01)*
	Issues with transport	*Don't have a car today and so it's difficult. (P01)*
	Inconvenient	*If someone said to me oh there's a baby class in [place name] or in the next village, I would probably go to it, but it's the fact that they tend to be that little bit further away. (P03)*
	Lack of parking	*Do yoga and things like that but the parking is terrible so that would tend to put me off. (P03)*
	Unable to locate appropriate classes	*I know they do Pilates and yoga, but that to me is not enough. I want to do a proper workout. (P08)*
Routine	Exercise second to baby's needs	*And I imagine that's what most mothers would say, their eating and exercise is secondary to the baby basically. (P01)*
	Baby's lack of routine makes exercising difficult	*When she was little, we weren't quite sure of her routines and you wouldn't be quite sure when you could take her out. (P03)*
	Need a routine to incorporate exercise into	*I think the main thing is that I need to get into a routine of doing regular exercise.(P06)*
	More to do now- less time to exercise	*If I really wanted to I could go out for a run while my husband baths my baby but I'm tired and I've got loads more jobs to do. (P02)*
Support	Depression- loneliness	*Not depressed and a bit crap. So when you are feeling like that, the last thing you want to do is go to the gym. Even if you know it will make you feel better. (P01)*

	Nobody to exercise with	*If I'm not going with someone am I going to be lonely? (P03)*
	Lack of advice	*The only advice I've got is stuff that, well I know myself, or look on the internet and that sort of thing. (P03)*
Time	Lack of time	*Just got a gym membership but it's a lot harder to find the time to go. (P09)*
Childcare	Lack of childcare	*We've got no family nearby so getting someone to look after him while I go to the gym or something just can't happen. (P06)*
	No freedom	*It's just not having the freedom to just go and do a gym class whenever you want. (P01)*
Tiredness	Too tired	*I get to like 7pm I'm just like so exhausted from entertaining him all day. (P06)*
Motivation and enjoyment	Not feeling up to it	*Because there's no way after a year my body is ready to go back to playing hockey. Well it would be ready to go back to playing hockey, but I would be frustrated that it wasn't at the same level as it was before because I've had a year off. (P04)*
	No motivation	*I could do it every night if I had any motivation, but I have very little. (P06)*
	Not enjoying it as much as before	*(weakened pelvic floor) stops me enjoying it (exercise) as much as I used to enjoy it. (P10)*
Cost	Too expensive	*I'm on statutory maternity pay, so that's another like barrier for me because it's just like well I can afford to go to the gym because it's like 10 pounds a month but I don't know how much I'll be able to go to the baby exercise classes. (P05)*

Breastfeeding	Issue with breastfeeding	*I don't express, so there's literally no one else to feed her other than me. (P05)*
Confidence	Lack of confidence	*I can go to a class for her because it's easy because it's her focus. But a class for me is a bit more oh not quite sure. (P03)*

Table 3.4 Perceived barriers to healthy nutrition in the postpartum period.

Nutrition Barriers (Postpartum)		
Theme	***Sub-theme***	***Example Code***
Time	No time to cook	*Even though he's eating food that we could eat, I just think once I've fed him my food is cold, he's wanting then entertaining, so the time thing is a real like an issue in that sense. (P06)*
	Less time to cook	*He fills so much of my head at the moment and thinking about him and doing all the extra washing and extra responsibilities and jobs that come with having him, I struggle to fit time in thinking about food prepping and meals and stuff. (P09)*
Tiredness	Eat crap, feel tired, feel more crap	*Lack of routine and lack of motivation sometimes and just being tired and craving crap. (P09)*
	Lack of sleep	*But that (tiredness) just leads into like unhealthy eating habits because when I'm like up all night I just think basically how am I going to treat myself for doing this stint all night. (P06)*
Routine	Eating second to baby's needs	*When I was looking after [baby's name] all the time you'd live on toast or a sandwich or whatever and I needed some structure. (P02)*
	Baby's lack of routine	*I'm hoping that as he gets bigger and as he gets into more of a routine then that will change. (P07)*
	No routine	*Lack of routine and lack of motivation sometimes. (P09)*

Support	Need support [at home]	*My husband and I we really need to support each other in it because if one of us does it doesn't really work because you're sort of living together and eating together. (P03)*
	Someone else doing the shopping [no control over choices]	*Because he does the bloody shopping he doesn't always get everything that I want, he'll get what he wants. So there is not necessarily enough stuff for me to eat and for me to think that's what I would really like to eat and I can make something really healthy with that. (P05)*
Motivation and enjoyment	Lack of motivation	*So I can be quite lazy and so can my husband and If I say I can't be bothered to cook we'll just go for a takeaway or something. (P04)*
Breastfeeding	Breastfeeding as an excuse to eat more	*I was of the opinion that I was breastfeeding so it didn't matter, calories didn't matter because you were feeding for her… I would go for chocolate, crisps, doughnuts, all that kind of stuff and in my head I thought that was okay because I'm breastfeeding, using up the calories, but clearly not. (P04)*
Restraint	Have treats when tired, no restraint	*It is just having a few treats, especially when you're tired. You kind of, you want a little bit of a chocolate hit for the energy. (P01)*

Table 3.5 Influences on quality of life in the postpartum period.

Quality of Life (Postpartum)		
Theme	***Sub-theme***	***Example Code***
Lifestyle	Exercise	*I know when I have a decent amount of exercise it makes me feel better. (P03)*
	Healthy eating	*It affects my mood in a negative way if I don't feel happy with what I'm eating. (P05)*
Sleep	Lack of sleep	*I am tired and I'm hungry, but I just felt really, really low, and like I looked at the symptoms and stuff and I am definitely a bit postnatal. And he's (partner) like "babe you're not you'll be fine you literally just need some good sleep." And then I had a couple of hours sleep and I woke up and I felt loads better. (P05)*
Loneliness	Loneliness affecting mood	*It's lonely, and you get cabin fever and you're staring at the same four walls. It's hard. That was when, breastfeeding with her, it was hard, because I couldn't go out. (P08)*
Freedom	Lack of freedom	*Because you can't just nip out and go shopping and stuff, like before when I was off, before I had her, I would like go out with my friends and stuff and meet them for lunch and whatever and then I'd go off to town shopping or nip up to (place) to see my parents or that sort of thing, just go ahead and do whatever I wanted whenever I wanted. And now I can't do that so that just makes it, you just kind of feel trapped. (P05)*

3.4.1 Practical Applications

It is evident that postpartum women experience a range of barriers to exercise and healthy eating during and following pregnancy. Postpartum women identify barriers specific to pregnancy and the postpartum period, but also describe universal barriers which may be experienced by the general population. We believe that this information, and formative work, is vital and should be considered when designing and delivering lifestyle interventions in overweight and obese postpartum women. We have, therefore, provided a list of suggested practical applications to assist researchers when designing lifestyle interventions with the aim of encouraging postpartum women to overcome perceived barriers to a healthy lifestyle and improve short- and long-term health outcomes (Table 3.6 and 3.7). Furthermore, medical professionals should utilise this information in primary healthcare settings when encouraging women to engage in healthy lifestyle behaviours before, during and following pregnancy.

Table 3.6 Postpartum exercise barriers and suggested practical applications for future interventions**.**

Exercise Barriers (Postpartum)	
Theme	***Practical Application***
Medical Complications	Individualised, incremental increases in exercise levels/intensity throughout an intervention. Recruitment following 6-8-week postpartum health check/received approval from general practitioner to resume physical activity following the birth.
Convenience	At home exercise programmes.
Routine	Emphasise the importance of exercise for maternal health and support mothers in incorporating exercise into daily routines. Design exercise programmes whereby sessions can be completed in short time periods and incorporated into busy routines.
Support	Encourage support at home from family and friends. Include other forms of support (e.g. technology) through Facebook/WhatsApp groups whereby mothers can support each other.
Time	Design exercise programmes whereby sessions can be completed in short time periods and at different times of the day.
Childcare	At home exercise programmes where the baby can be incorporated into exercise sessions/sessions can be completed during, for example, nap time or when the partner is home/available for childcare.
Tiredness	Encourage women to complete sessions/walks when they feel less tired/able. Emphasise the importance of walking and exercise for maternal health and provide consistent support to encourage an active lifestyle.
Motivation and enjoyment	Include a variety of exercises, and types of exercises (endurance and strength) to reduce boredom and increase enjoyment.
Cost	Free sessions.
Breastfeeding	Encourage women to develop a plan to exercise around the breastfeeding routine. Exercising at home also allows the mother to attend to breastfeeding needs.
Confidence	At home exercise sessions, without the judgement or suspected judgement of other women in group exercise classes. Group support (through technological means) to encourage increases in self-confidence.

Table 3.7 Postpartum nutrition barriers and suggested practical applications for future interventions.

Nutrition Barriers (Postpartum)	
Theme	***Practical Application***
Time	Include quick recipe suggestions as part of the nutrition intervention and, where possible, encourage childcare support from family members/friends to allow time for food preparation.
Tiredness	Encourage women to employ a range of behavioural techniques (e.g. batch cooking when not tired) so as to stay on track when feeling tired.
Routine	Support women to develop a daily/weekly routine whereby time is allocated to, for example, planning the weekly food shop and batch cooking in advance.
Support	Encourage support at home from family and friends. Include other forms of support (e.g. technology) through Facebook/WhatsApp groups whereby mothers can support each other on the programme.
Motivation and enjoyment	Utilise technological support to increase motivation and encourage other women to provide recipe suggestions/healthy eating tips on social media groups (e.g. Facebook/WhatsApp).
Breastfeeding	Provide education on the caloric requirements of breastfeeding as part of the intervention.
Restraint	Emphasise the importance of a healthy diet and motivate women to develop restrained eating behaviours to encourage healthy maternal and offspring outcomes.

3.5 Discussion

This study sought to understand overweight and obese women's experiences of physical activity, diet and QoL during and following pregnancy, particularly their perceived barriers to exercise and healthy eating. Previously, little work has examined overweight and obese women's experiences, and to our knowledge, we are the first to conduct formative research in women with a BMI >25 kg·m^2 prior to the design and implementation of postpartum lifestyle interventions in the United Kingdom.

Whilst a number of previous investigations have highlighted many exercise and nutritional barriers during pregnancy and the postpartum period (Coll et al. 2017; Saligheh et al.2016; Powell et al. 2007; Hurley et al. 2005), little work exists in the overweight and obese population. In the current study women highlighted a range of barriers to a healthy lifestyle during and following pregnancy, some of which were specific to pregnancy and the postpartum period and others which were universal and could be experienced by the general population. Regarding exercise during pregnancy, overweight and obese women in the current study highlighted a lack of support and time, and tiredness as universal barriers to exercise engagement. Other barriers unique to pregnancy included nausea, maternal size, fear of miscarriage and the cost of pregnancy-specific exercise classes. Our findings highlighted a perceived lack of support from medical professionals (*e.g.*, general practitioner and midwife) and discouragement with regards to engaging in physical activity from friends and family, which agrees with previous research (Sui, Turnbull, and Dodd 2013; Flannery et al. 2018; Harrison et al. 2018). Harrison et al. (2018) conducted a systematic review to examine the attitudes, and perceived barriers and enablers to physical activity during pregnancy. Forty-nine papers from 47 studies and 7655 participants were included, however only 6 studies (*n*=776) were identified that included overweight and obese women. Nonetheless, our work offers agreements with Harrison et al. (2018) whereby pregnancy discomforts (*e.g.*, nausea, pain and increasing size), lack of time and fatigue were also identified as barriers to exercise engagement. One of the papers (Sui et al. 2013) included in the Harrison et al. (2018) review conducted semi-structured interviews with 26 overweight pregnant women with the aim of understanding barriers to and enablers of initiating healthy behaviour change during pregnancy. Interpersonal barriers were most frequently cited throughout the interviews with women often describing a lack of time due to prioritising work and family commitments above their own health. The cost of exercise classes and healthy eating, and a lack of support (*e.g.*, from friends and family) were also identified as barriers to making healthy changes during pregnancy. Physiological barriers such as tiredness and pregnancy complications were described whilst cognitive barriers included a lack of knowledge of safe exercise during pregnancy and concerns about the safety of the baby whilst exercising. The results from the current study offer indications that, in the United Kingdom, overweight and obese women experience similar barriers to exercise during pregnancy as those residing in Australia (Sui et al. 2013). This work was vital to ensure that an accurate depiction of women's experiences was obtained prior to the delivery of future lifestyle interventions. Given that overweight and obese women prefer to defer weight management to the postnatal period and view healthy eating as more important than physical activity for maternal and infant health (Weir et al. 2010), future interventions in overweight and obese women must provide detailed information on the importance of physical activity and how to exercise safely during pregnancy, and encourage higher levels of support, both from friends and family and the research team. Exercise programmes, specifically, must be affordable and adaptable to fit into women's time constrained schedules. Tiredness is more common during the first trimester, which is often due to increases in levels of progesterone at the start of pregnancy (Magon and Kumar, 2012). In future, practitioners should look to commence antenatal lifestyle interventions in overweight and obese women from the second trimester onwards when women are better adjusted to the physiological demands of pregnancy.

As well as describing a range of barriers to exercise engagement, women in the current study described numerous issues when attempting to eat healthily during pregnancy. Pregnancy specific barriers such as nausea, in particular morning sickness and being repulsed by certain foods, were identified as preventing healthy eating. Universal barriers included unhealthy cravings, tiredness and a lack or loss of restraint. Previously, pregnancy symptoms such as nausea and vomiting, low socioeconomic status and maternal depression have all been shown to limit diet quality in pregnancy (Finch, 2003; Hurley et al. 2005; Pepper and Craig Roberts, 2006; Powell et al. 2007). However, a large proportion of this work has been carried out in low-income countries and little research has focused on understanding specific barriers to healthy eating in pregnant women, especially in those with overweight and obesity. Begley (2002) assessed barriers to initiating and maintaining dietary change during pregnancy in 90 women of childbearing age who were pregnant or planning a pregnancy. A lack of knowledge and advice on what constitutes a healthy diet, the promotion of listeria awareness seen as giving food negative connotations and healthcare professionals lacking the time and knowledge to discuss nutrition were all identified as preventing healthy changes during this time. It is evident that women who diet habitually in the preconception period are less restrained and gain more weight during pregnancy (Clark and Ogden, 1999; Fairburn et al. 1992), which may be associated with a lack of dietary training provided to medical professionals on specific nutritional requirements (Lucas et al. 2014) and support on how to address pregnancy weight in a non-judgemental manner (Flannery et al. 2019). The current work has begun much needed investigations into barriers to healthy eating in overweight and obese pregnant women. Further work in high-income countries is urgently required to further understand these perceived barriers. The development of effective nutritional education and support programmes is also required to improve the dietary behaviours of pregnant women, regardless of BMI.

The postpartum period is an opportune time to implement long-term healthy lifestyle changes (Faria-Schützer et al. 2018), due to the fact that women are more aware of their nutrition and bodyweight (Lyu et al. 2009; Wilkinson et al. 2015), and are motivated to improve both their own health and that of the baby (Hanson et al. 2017; Arabin and Stupin, 2014). Individuals in the present study, however, described a range of perceived barriers to exercise and healthy eating. Universal barriers to exercise engagement included a lack or loss of routine, time, convenience and tiredness. Medical complications arising from the birth and difficulties in locating appropriate postpartum exercise classes were cited as postpartum specific barriers. Findings by Saligheh et al. (2016) agree with those in the current study whereby participants described universal barriers such as fatigue and substantial time constraints from preventing postpartum exercise engagement, as well as a lack of access to appropriate and affordable classes and public transport. However, Saligheh et al. (2016) do not report the weight status of participants so we are unable to conclude if these barriers are concurrent across BMI categories or specific to overweight and obese women. Given that unfavourable maternal and child clinical outcomes relate linearly to BMI (Stubert et al. 2018), it is perhaps not surprising that overweight and obese women in the current study identify medical complications as the most common perceived barrier to postpartum exercise. Previously, medical limitations and recovery from caesarean section were identified as a main barrier to exercise engagement in only 4.7% of a mixed BMI postpartum population (Evenson et al. 2009). Therefore, healthcare professionals must work more closely with overweight and obese women to support and encourage a safe and timely return to, or initiation of, exercise following the recovery from childbirth.

In our study individuals also mentioned prioritising the baby's health above their own and often regarded classes for the baby as more important and easier to attend as the focus was on the baby, rather than the mother. Women also described a lack of advice from medical professionals and a lack of support from friends and family as preventing postpartum exercise engagement. These findings agree with previous work whereby new mothers consider parenting as the most important responsibility following childbirth (Paskiewicz, 2001), and a lack of advice from professionals regarding appropriate exercise programs has been identified as a barrier to postpartum exercise participation in a cohort of women where 52.7% of them were overweight or obese (Evenson et al. 2009). When designing future postpartum lifestyle interventions in overweight and obese women, we will pay careful consideration to the fact that women in the current study describe a lack of support, time and childcare as preventing exercise engagement during this time. For example, exercise interventions may follow an at-home circuit style programme whereby mothers do not require childcare and can complete sessions in a short time period. The importance of maternal health will be conveyed, and appropriate education and technological support will be provided by the study delivery team.

Women in the present study identified a lack of time, tiredness and a lack of partner support as universal barriers to healthy eating, whilst breastfeeding and difficulties with childcare were described as specifically preventing postpartum healthy eating practices. More work has focused on understanding barriers to a healthy lifestyle (exercise and diet) rather than healthy eating, specifically, although our findings still offer substantial agreements with this previous work (Carter-Edwards et al. 2009; Miller et al. 2002; Watson et al. 2005). Carter-Edwards et al. (2009) reported that time availability, a lack of support from family and friends and prioritising other life commitments above health as reasons for postpartum women declining the invitation to take part in a lifestyle intervention. Women in the current study also described using breastfeeding as an excuse to eat more, which agrees with the results by Lyons et al. (2019) who described that obese women perceive the need to consume more calories in order to maintain milk supply than non-obese women. During breastfeeding, overweight and obese women do not require any additional energy and can safely restrict their energy intake without compromising the growth and development of their offspring (Gluckman et al. 2015). This can be achieved through a 500 kcal/day reduction in overall calorie intake (Lovelady et al. 2000). Given that the breastfeeding rate for England has most recently been reported as 48.1% by Public Health England in January 2020 (Public Health England, 2020), better education on the importance of a healthy lifestyle, including appropriate caloric intakes for overweight and obese breastfeeding mothers, is vital to encourage positive short- and long-term maternal health outcomes. In the current study participants described that exercise and healthy eating had a positive influence on QoL. A lack of sleep, loneliness and a loss of freedom since the baby had arrived were identified as factors that negatively influenced QoL. In the six weeks following childbirth QoL has been shown to progressively decline (Martínez-Galiano et al. 2019) however, to our knowledge, this is the first study to offer insights into the factors that influence QoL in overweight and obese postpartum women through the use of semi-structured interviews. de Oliveira et al. (2015) previously explored the effect of demographic characteristics on QoL in postpartum Brazilian mothers, however BMI status was not reported. Participants completed a demographics questionnaire and an adapted version of the Maternal Postpartum Quality of Life Tool (MAPP-QoL; Hill et al. 2006). In this cohort of postpartum women, the best predictors of QoL were being married or living with a partner and being of white ethnicity. Additionally, de Oliveira et al. (2015) identified a lack of social support, low levels of education and a lack of knowledge regarding postpartum QoL as having a negative influence on QoL. The results from the current study and those by de Oliveira et al. (2015) contribute to a better understanding of the factors influencing postpartum QoL and the need to identify sub-groups at risk of low postpartum QoL that may require further support, however further work is urgently required in overweight and obese women.

Herein, we have provided valuable information to support the design and delivery of lifestyle interventions in overweight and obese postpartum living in the United Kingdom. A comprehensive understanding of perceived universal and pregnancy and postpartum barriers to a healthy lifestyle is imperative prior to designing and delivering lifestyle interventions. Only a small number of previous studies have completed formative work prior to implementing lifestyle interventions in postpartum women and have provided mixed results. For example, Graham et al. (2016) completed a needs assessment of the barriers to weight-related health behaviours prior to designing an online intervention to prevent excessive GWG and promote the return to pre-pregnancy BMI in postpartum women. In short, participants in the intervention group were granted access to a website containing three behavioural change tools: physical activity and dietary goal-setting, self-monitoring and a weight gain tracker (Graham et al. 2014; Olson et al. 2018). Both the intervention participants and the placebo group had access to online information tools, blogging features and event reminders. Results indicated that there was no significant difference between the intervention (48.1%) and control (46.2%; p=0.12) groups in the proportion of women that experienced excessive GWG. The authors concluded that the low usage of the behaviour change tools (46.1%) in the intervention group and the similarity between the control and intervention treatments may explain the absence of differences between groups. In other areas, formative work carried out prior to the implementation of interventions has proven more effective. Danaher et al. (2012) included formative work with focus group participants and usability testers that contributed towards the design of a web-based intervention aimed at ameliorating the symptoms of postpartum depression (Danaher et al. 2012). Results from the intervention revealed that 55% of participants met the criteria for minor or major depression prior to the program and at the post-test 90% no longer met the criteria (Danaher et al. 2013). In the overweight and obese postpartum population, it is evident that formative work is still required to identify the necessary tools to promote significant weight loss and improve both maternal and infant outcomes.

3.6 Conclusion, Limitations, and Future Directions

Our study included women who were 12-52 weeks postpartum, as such one limitation was the large range in the time since delivery between participants. Future research should look to engage with postpartum women at set time points to understand any similarities and differences in women's experiences at specific stages of the postpartum journey. Interviews were also only conducted at one time point. In future, an understanding of women's perceived barriers at different time points will enable an understanding of the prominence of certain barriers throughout the postpartum period. The range in interview lengths may also indicate that some participants were not fully engaged or had few, or no, perceived barriers to a healthy lifestyle during and following pregnancy. In some instances, a follow-up interview would have been useful. Finally, examining the relationship between participants' barriers to a healthy lifestyle and engagement with local lifestyle support services would be useful to identify any areas within such services that could be improved upon to encourage healthy long-term outcomes.

The current study was novel in design whereby we have gained valuable insights into overweight and obese postpartum women's experiences of physical activity, diet and QoL during and following pregnancy, and provided suggestions for the practical implementation of future lifestyle interventions. Women identified a range of perceived barriers to exercise and nutrition during and following pregnancy. During pregnancy the most frequently identified barriers to exercise were tiredness and support whilst cravings and nausea were most frequently cited as preventing healthy eating. In the postpartum period, the main barriers to exercise engagement were medical complications, routine and time whilst time and tiredness were viewed as the most prominent barriers to healthy eating. Women also described that lifestyle and sleep were the two biggest influences on postpartum QoL. Overweight and obese women appear to encounter several universal barriers experienced by the general population and describe similar challenges to normal weight pregnant and postpartum women when attempting to engage in a healthy lifestyle. Based on our findings, overweight and obese postpartum mothers do not describe any unique barriers to a healthy lifestyle, other than medical complications preventing exercise engagement. Both the universal and postpartum specific barriers should be considered in future intervention work. We intend to use the results from the current study along with previous work to inform the design of our future lifestyle intervention studies delivered in overweight and obese postpartum women.

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Chapter 4: Patient and Public Involvement: Using Formative Work to Underpin A Future Lifestyle Intervention

4.1 Introduction

PPI has been recommended as an important inclusion in research, alongside qualitative work, which is especially useful in the early stages of the design of complex intervention studies (Morgan, Thomson, Crossland, Dykes, & Hoddinott, 2016). PPI is often referred to as work carried out by patients (individuals with a medical condition who receive health treatment) or the public (country residents), specifically with the view to obtain the thoughts and opinions of individuals prior to conducting research intended for their benefit (Morgan et al., 2016). The purpose of PPI is to enhance the depth, clarity and credibility of the research and the applicability of findings, and to ensure direct links between practice-based evidence and evidence-based methodology (Boote, Baird, & Sutton, 2011; Braye & Preston-Shoot, 2005; Smith et al., 2009). Various international organisations recognise the importance of including PPI in the research process, for example the National Institute for Health Research (National Institute for Health Research, 2013) and US National Institutes for Health (National Institutes of Health, 2011). The Medical Research Council also recommends the inclusion of qualitative interviews, observations and focus groups during the development of complex interventions to incorporate varying views and perspectives into the study design (Medical Research Council, 2000). PPI has been included in a variety of settings, such as drug development research (Evans et al., 2018), social care research (Brett et al., 2014) and in the development and delivery of health services provided by the National Health Service (NHS) (Boudioni, McLaren, & Lister, 2017). Recently, PPI work has been conducted to understand experiences of healthy eating and weight management during pregnancy (Abayomi 2020). Focus group style methodology was adopted and two PPI representatives inputted towards all aspects of the study. Findings demonstrated that pregnant women often receive information regarding what they should not do, but would prefer more positive health messages focusing on what they should do. It was noted that midwives must consider their communication on topics of diet and weight management, whilst maintaining the unique relationship with pregnant women. The development of a digital intervention was also described as an avenue to improve pregnancy-specific nutrition information, and to empower midwives to confidently communicate patient-centred healthy eating messages during pregnancy.

Furthermore, scoping focus groups have been implemented prior to the implementation of a postnatal lifestyle intervention for overweight women with previous gestational diabetes (PAIGE) (Holmes et al., 2018). Feedback from these focus groups directed the tone and content of the subsequent intervention, which was comprised of an education session, a free 12-week referral to a commercial weight management programme, a pedometer, and structured text and telephone support in addition to routine care (*n* = 29). The control group received routine care only (*n* = 31). At 6 months, PAIGE resulted in significant weight loss compared with the control group (mean $\pm$ SD, 3.9 $\pm$ 7.0kg vs. 0.7 $\pm$ 3.8kg; p=0.02), highlighting the potential benefits of including PPI into the research design process. It is interesting to note that, despite the success of the intervention and the pre-intervention formative assessment, 60 women declined the offer to participate in the PAIGE study and cited various barriers to involvement, such as, childcare, lack of time and unwilling to leave the baby. The authors recognised that future research should also pay careful consideration to these factors. Based on the findings and experiences of the PAIGE study, it might also be prudent to also conduct a post-intervention assessment [see Chapter 6].

As detailed in Chapter 3, overweight and obese postpartum women experience a range of perceived barriers to exercise and healthy eating during and following pregnancy. The main issues were a lack of routine, time, convenience, and enjoyment. Therefore, the aims of the current study were to: 1) use the data from Study 1 (Chapter 3) to design a lifestyle intervention that aimed to overcome or reduce the impact of these perceived barriers on the women's ability to comply with the programme; 2) use PPI to discuss the perceived barriers highlighted in Study 1 (Chapter 3), to see which were consistent and if any new themes emerged; and 3) gather the opinions of postpartum women regarding a proposed lifestyle intervention aimed at reducing perceived barriers to a healthy lifestyle and improving weight management and health.

4.2 Methods

4.2.1 Recruitment and participants

In June 2018, two PPI sessions (PPI1 and PPI2) were conducted with postpartum women who were between 12 and 52 weeks postpartum. Primiparous and multiparous women were included. Ten women took part in the PPI sessions, 5 in each session. Participants were recruited through social media (e.g. Facebook, Twitter) and word of mouth. In some instances, snowball sampling was employed whereby participants identified other individuals who fulfilled the inclusion criteria.

4.2.2 Research design

Both PPI sessions took place in a private room at Nottingham Trent University Clifton Campus and were recorded using a Dictaphone to allow for transcription and analysis. The sessions were advertised and run as coffee mornings with drinks and refreshments provided, creating an informal setting and putting participants at ease. The first ~20 minutes allowed women to get to know each other before the Dictaphone was started and the session content was delivered.

4.2.3 Proposed Intervention Design

Prior to the delivery of the PPI sessions Version 1 of the intervention was created, based upon (i) prior studies (both by our lab group and other authors) and (ii) the perceived barriers highlighted by women in Study 1 (Chapter 3). For example, Huseinovic et al. (2016) delivered a 12-week lifestyle intervention that was successful in encouraging significant reductions in bodyweight compared to a control group, therefore the participants in these PPI sessions were asked if a 12-week intervention would appeal to them. Our lab group has also had previous issues recruiting and retaining postpartum women to a control group, therefore a tracking period was included in the design to understand free-living behaviours prior to enrolment in the intervention. This approach was taken so the strongest research design, from a scientific perspective (Table 4.1), could be married with the most acceptable design, from the perspective of the end-users (Table 4.2). In some instances, there was both a scientific rationale and a rationale to enhance the acceptability of the end user (*e.g.* the inclusion of element of choice), therefore details are provided in both tables 4.1 and 4.2. This resulted in the schedule shown in Figure 4.1.

Table 4.1 The scientific approaches used to underpin the proposed study design; these were based on previous literature [references provided] and previous experience by the supervisory team.

Approach	Rationale
Inclusion of tracking period	To understand if taking part in a study (prior to intervention engagement) promotes behaviour change. In addition, this approach mitigates previous issues encountered by our laboratory group with recruiting and retaining control groups.
Inclusion of pre-recorded videos detailing diet and exercise interventions	To enable the delivery of standardised information to all participants.
Withheld information regarding numbers enrolled in each intervention group	To allow participants to choose if to be in the diet or exercise intervention arm without any external influences affecting their decision (*e.g.* participants may feel that they need to 'make up the numbers' in the group with fewer other participants or may wish to be part of a bigger group).
Inclusion of a 24-hour period following the pre-intervention visit during which participants make the choice of engaging in either the diet or exercise intervention	To allow participants the opportunity to speak with their support network (family and/or friends), such that they can make an informed and unhurried decision.
Inclusion element of choice regarding engagement in either diet or exercise intervention	In line with Self Determination Theory, autonomous motivation has previously been associated with improvements in physical activity and healthy lifestyle behaviours in other populations (Hagger & Chatzisarantis, 2009; Knittle et al., 2018; Ng et al., 2012; Teixeira, Carraça, Markland, Silva, & Ryan, 2012).
Food recalls only requested on weekdays	Dietary behaviours are often different at the weekend compared to weekdays (Monteiro et al., 2017), so to allow for valid comparisons across the study period.
Inclusion of EPDS questionnaire	To allow for the detection of participants who may need to seek advice from a medical professional and who may subsequently meet the exclusion criteria following enrolment.
Inclusion of follow-up period	To define the effect of the intervention following the removal of associated support.
Inclusion of optional home visits at times where lab-based measures were not collected (visits 3-5)	To attempt to minimise participant burden.

Table 4.2 The tailored approaches used to underpin the proposed study design; these were based on the findings from Study 1, Chapter 3 (*i.e.*, from the end-user perspective).

Approach	Rationale
Inclusion of element of choice regarding engagement in either diet or exercise intervention	1. As a result of various individual circumstances highlighted by women in Chapter 3 (*e.g.* some women said that someone else did the food shop, some women described issues with childcare and associated difficulties with exercise engagement). As such, this approach allows women the opportunity to elect which behaviour (diet or exercise) they could alter more easily given their circumstances. 2. Women in Chapter 3 detailed various medical complications, and to varying degrees, that affected their ability to engage with exercise following childbirth. The inclusion of the element of choice was also thought to allow women the chance to decide if they felt ready to return to exercise (even if they had received approval from the GP at the 6 to 8 week postpartum check), rather than being told they were to engage with an exercise program that they may not feel ready for. 3. This choice was hoped to encourage higher levels of motivation and enjoyment (a barrier identified in Chapter 3) as women were able to elect which intervention was more appealing to them.
Inclusion of optional home visits at times where lab-based measures were not collected (visits 3-5)	Convenience was cited as a barrier to physical activity in Chapter 3. It was thought that the option of home visits would make it as convenient as possible for women to take part in the study whilst making healthy changes to their lifestyle.
Inclusion of 12-week intervention	It was thought that the intervention length would allow sufficient time for one behaviour (diet or exercise) to be incorporated into a woman's routine, as a lack of routine was cited as preventing both healthy eating and exercise engagement in Chapter 3.

Option to include baby in the exercise sessions	Childcare was highlighted as a barrier to physical activity in Chapter 3. It was thought that the option to include the baby during exercise sessions would eradicate the issue of childcare.
Flexibility regarding time and location of exercise sessions.	Lack of convenience and time was highlighted as a barrier to physical activity in Chapter 3. It was thought that the flexibility of allowing women to exercise where and when suits them would allow for easier engagement.
Option to exercise individually or in a group	Confidence in exercise classes was cited by some women as a barrier to exercise in Chapter 3. It was thought that the delivery of individual-based sessions with the option of arranging group walks would appeal to all women.
Option to focus on strength-based, aerobic-based or a combination of both in exercise sessions.	Reduced strength and a lack of motivation/enjoyment were described as barriers to exercise by women in Chapter 3. It was thought that giving women the option of focusing on strength/aerobic/mixed exercise would allow women to choose what appealed to them most within their individual physical capabilities.
Inclusion of quick recipes as part of diet intervention.	Time was cited as the most common barrier to postpartum healthy eating practices in Chapter 3. Therefore, an understanding of women's acceptability of quick recipes as part of the dietary intervention was sought.

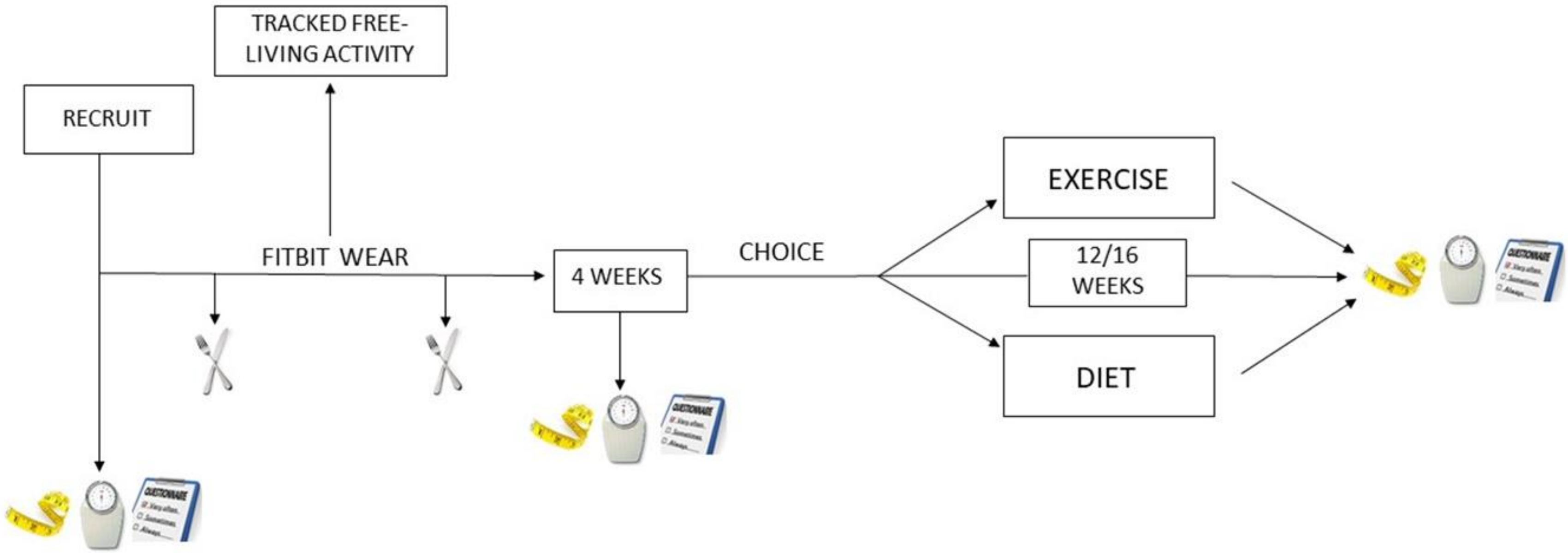

Figure 4.1 Proposed Intervention Design version 1, as shown to the participants in the public and patient involvement sessions.

4.2.4 Research protocol

A set of introductory questions and a main interview guide were created for use during both PPI sessions (Figures 4.2 and 4.3). Women in the PPI sessions were initially asked for their opinions on the barriers to a healthy lifestyle identified by women in Chapter 3; specifically, a lack of routine, time, convenience and enjoyment were cited as preventing engagement in a healthy postpartum lifestyle. The main interview guide was created to understand potential intervention design strategies that may reduce the perceived barriers highlighted by women in Chapter 3 (see Table 4.2).

Prior to commencing the session, women were provided with printouts of the proposed intervention design (Figure 4.1). The proposed design was explained and referred to during the delivery of the study design questions. For example, women were asked if they would prefer to be weighed at different points throughout the intervention or just at the start and the end. The proposed intervention plan detailed three weigh-in points, and women were asked for their opinions on this. The 4-week tracked period was explained to women and they were asked to provide detail on the length of this, especially in relation to obtaining a representation of current lifestyle over this time.

Following the delivery of all set interview guide questions, women were given the opportunity to provide any additional comments related to any aspect of the proposed intervention (both study design and content of the intervention). The following questions were also prepared onto paper strips and distributed to obtain written, anonymous opinions;

1. Would you prefer an exercise/healthy eating programme that is 12 weeks or 16 weeks?
2. Would you prefer to engage in an exercise or dietary programme?
3. If you were eating unhealthily and doing very little exercise, do you think you would be more likely to change your diet or increase your activity levels?
4. Would it be too overwhelming if you were to attempt to change both your diet and physical activity?

4.2.5 Data Analysis

A descriptive approach was adopted to present the findings of the close-ended questions, with results split by PPI group (PPI1 or PPI2). Open-ended questions were analysed using a modified thematic analysis (Braun and Clarke, 2006); the full process is described in section 3.1.2.7.

> BARRIERS TO EXERCISE AND HEALTHY EATING
>
> Women in my last study highlighted the following barriers to physical activity during pregnancy; tiredness, lack of support, physical constraints, work, lack of convenience, health and safety concerns, lack of time and cost. Would you agree? Would you add anything?
>
> Regarding barriers to physical activity following pregnancy women described the following; medical complications from the birth, lack of convenience, lack or loss of routine, lack of support, time, childcare, tiredness, lack of enjoyment, cost, breastfeeding and lack of confidence. Would you agree? Would you add anything?
>
> Regarding barriers to healthy eating during pregnancy women described the following; cravings, nausea, lack or loss of restraint and tiredness. Would you agree? Would you add anything?
>
> Regarding barriers to healthy eating following pregnancy women described the following; lack of time, tiredness, lack of routine, lack of support, lack of motivation, breastfeeding as an excuse to eat more and lack of restraint. Would you agree? Would you add anything?

Figure 4.2 PPI Introductory Questions

EXERCISE INTERVENTION

Would you prefer to engage in an exercise programme that is home-based or outside of the home (*e.g.,* a gym, park or community centre)?

Would you prefer to exercise in a group or on your own?

Do you think you would be able to maintain better engagement if you could exercise with/without your baby?

What time of day would be most convenient for you to exercise? Morning/afternoon/evening?

Would you prefer to take part in a strength/aerobic based programme?

Would a walking-based programme be of interest to you or would you prefer exercise at a higher intensity?

DIETARY INTERVENTION

If you were to engage in a healthy eating programme, would you prefer to record your food by weighing it, completing a food diary or by using an app?

Would being sent ‘quick recipes’ be useful for you if you were to engage in a healthy eating programme?

Are you aware of how to consume a balanced diet or would you require some nutritional advice prior to beginning the programme?

STUDY DESIGN

Would you prefer to be weighed at certain points during the programme or just at the start and end?

Do you think that receiving motivational texts throughout the programme would be beneficial for you?

Would a 4-week tracked free-living period using food diaries and a Fitbit be a enough time to gain a true representation of your current lifestyle before the intervention started?

Would you prefer to choose or be told that you were part of the exercise or diet programme?

Would you enjoy being part of a group forum where you could share ideas/keep in touch with other people in the programme?

Figure 4.3 Interview Guide

4.3 Results

4.3.1 PPI Introductory Question Responses

Results from the set of introductory questions (Figure 4.2) demonstrated that this group of postpartum women agreed with the findings from Chapter 3. Whilst women in the current study provided further detail on some of the barriers presented to them and shared their experiences, there were no suggestions made regarding any other barriers that prevented engagement to exercise and healthy eating during and following pregnancy.

4.3.2 PPI Group Responses

4.3.2.1 Content of Exercise and Dietary Interventions

The results from the exercise-based questions are shown in Tables 4.3 (PPI1) and 4.4 (PPI2), whilst the nutritional intervention findings are displayed in Tables 4.5 (PPI1) and 4.6 (PPI2).

Table 4.3 Results from questions asked about the design of the exercise intervention (PPI1).

PPI Question	Result	Example Quote(s)
Setting?	Outside [All participants]	"You spend too long inside the house that you need that time out"
Group/individual?	Group [All participants]	"Yeah I think you're more motivated as part of a group to do something"
Baby inclusion/exclusion?	Inclusion [All participants]	"The baby needs to come otherwise I'm not going to make it because I've got no childcare"
Time of day?	Morning/afternoon/evening [Mixed opinions]	"It needs to be after the school run" "I think two o'clock in the afternoon" "I think I'd be tempted with evening once I go back to work"
Strength/aerobic based?	Combination [All participants]	"Or you do one that's mainly aerobic and some strength built in and then the other time strength with a bit of aerobic"
Intensity of exercise?	Gradual increase and Individualised [All participants]	"I guess it would need to be gradual" "It depends how soon after the baby you are starting… and how active you were"

Table 4.4 Results from questions asked about the design of the exercise intervention (PPI2).

PPI Question	Result	Example Quote(s)
Setting?	Outside [All participants]	"Yeah, I think sometimes having to make yourself go, you're more likely to keep appointments"
Group/individual?	Group [All participants]	"Meet people and do some exercise at the same time"
Baby inclusion/exclusion?	Inclusion/exclusion [Mixed opinions]	"It depends on what sort of exercise you're talking about, it's easy to take a walk with the baby in the pushchair, but if we're talking more of an exercise class, the baby is a distraction"
Time of day?	Morning/ evening [Mixed opinions]	"I'd say morning with baby" "Without baby, evening because partner is home"
Strength/aerobic based?	Combination [All participants]	"I think variety helps… you get bored after a few weeks when you're doing the same exercises"
Intensity of exercise?	Gradual increase and Individualised [All participants]	"I think given the option for us to make it more intense, rather than the class being more intense"

Results from Tables 4.3 and 4.4 reveal that women in both PPI sessions would prefer exercise sessions to be based outside and in groups. A few individuals in the second session made comments regarding the size of groups, with smaller (6-8 people) groups being preferable. Women in PPI 1 stated that the baby would have to be included due to issues with childcare whilst individuals in PPI 2 had mixed opinions, due to the baby being a possible distraction especially when they started crawling and walking. In terms of the time of day, women in both sessions were of differing opinions whereby some preferred morning and others preferred afternoons and evenings. A combination of both strength and aerobic exercise was preferred by all women in both groups in order to maintain variety, whilst an individualised and gradual increase in exercise intensity was the preference.

Table 4.5 Results from questions asked about the design of the nutritional intervention (PPI1)

PPI Question	Result	Example Quote(s)
Record food by weighing/food diary/phone app?	App [All participants]	"App because I wouldn't have to have a pen or paper on me"
Quick recipe ideas useful?	Yes [All participants]	"It would be useful to have, even just simple recipes for snack alternatives" "Yeah and stuff that isn't going to take loads of time for preparing"
Nutritional advice required?	Yes [All participants]	"Yeah I think it would be good just to have it standardised so everyone is on the same page"

Table 4.6 Results from questions asked about the design of the nutritional intervention (PPI2)

PPI Question	Result	Example Quote(s)
Record food by weighing/food diary/phone app?	App [All participants]	"Yeah app, so precise"
Quick recipe ideas useful?	Yes [All participants]	"I think recipes are good because it helps you to vary your diet a bit"
Nutritional advice required?	Yes [All participants]	"It would be good to have quite accurate information because sometimes if you look online or whatever you get all sorts of advice"

Three questions were asked specific to the design of the nutritional intervention. Results from tables 4.5 and 4.6 reveal that women in both sessions preferred the use of a phone application to record food intake as they viewed this method to be more precise and easier to use compared with weighing foods and using a food diary. Women agreed that quick recipe ideas would be useful in order to encourage variety in their diets and enable healthy snacking. Nutritional advice was seen as an important inclusion to the intervention as it meant women were aware of the constituents of a healthy balanced diet, and it helped to eradicate issues regarding conflicting online advice.

4.3.2.2 Opinions on Proposed Study Design

Regarding the proposed intervention design, firstly participants were asked if they would prefer to be weighed at different points or at the start and end of the programmes. All participants agreed that weigh-in points throughout the interventions would be preferred. One individual in PPI1 mentioned, "You've got to have the incentive to keep going so it's got to be in the middle as well" whilst another echoed these thoughts by saying, "I don't think there's any incentive because you can start and then at the end, if you weigh more, or whatever what are you going to do then?". Participants in PPI2 offered their opinions on the frequency of weigh in's. One individual said, "I think a monthly weigh-in would be useful, but not weekly" and another described how monthly weigh ins allowed for a better representation of longer-term weight change. She said,

> "Yeah, once a month, Because sometimes I think weekly can be a bit too much, can't it? Because like if you say you lose three pounds one week and then half a pound the next week you feel like a bit of a failure don't you?"

Participants were also asked if receiving motivational texts would be beneficial. There were mixed opinions regarding the usefulness of text messages, with some suggesting the inclusion of an optional phone call if there were any problems. One individual in PPI1 said, "You probably don't get around to even reading them [texts] half the time. Maybe a phone call though" and another added to this by saying, "And then if someone was having problems, they could discuss it with you." Participants in PPI2 described similar opinions by saying that the texts "makes you carry on" but "maybe a text and then, a text saying is everything going okay blah blah blah, and then if you reply and so no, they follow up with a phone call" would be useful to encourage sustained commitment to the programme.

One question aimed to understand individuals' thoughts on if a 4-week tracked free-living period using food diaries and a Fitbit accelerometer would be a sufficient amount of time to gain a true representation of lifestyle prior to the start of the interventions. In regard to the use of the Fitbit individuals in both PPI groups agreed that 4 weeks was a sufficient time for the novelty to wear off. One individual said, "Even with the Fitbit, you begin, don't you, you look at it in the beginning and then sometimes it just runs and it's just like, 'Oh yeah, I'm wearing it but I'm not bothered'" and another mentioned, "There's a period of time where there will be the novelty of it and because it's four weeks, it might average out." Similar opinions were expressed when individuals were asked about the food diaries. One participant in PPI1 described,

> "Because I think the first week, you'll get people going, "Somebody's going to look at this, I'm going to only eat fruit and veg for the whole day" and people will be really good. Yeah, and then as you go through, people will be "I'm just going to eat what I normally eat."

Another participant in PPI 2 also said, "So, if you maybe did like a full week's diary, so do an entire week, then it's harder to control what you're eating".

Another aspect of the intervention design that was considered was giving participants the choice of taking part in either an exercise or dietary intervention. Individuals in PPI1 believed the choice would increase the likelihood of success. One participant said, "Well I think naturally people like to choose and I think when you have more autonomy over your choices, then you would stick to it a bit more", whilst another explained:

> "Yeah, I agree with that. If you said to me, 'Well I want you to follow the diet', as soon as it stops working or I don't do it, 'Well I didn't choose that so it's not my fault I'm not losing weight. I didn't choose to do this. I would have done'… Do you know what I mean?"

Individuals in the second group had differing opinions on the matter. Whilst some said "I'd rather be assigned" and "Yeah, I'm not bothered which one I do either because my diet and exercise are both crap", others had more similar opinions to those in the first session as one woman said, "I'm the opposite, if you told me to do something I'd motivate myself to do it because I wouldn't want to let someone down". It must however be noted that women in the second group were less representative of the population for the intervention study (*i.e.*, the women in this group included normal weight women) and therefore some of them might have already been physically active and engaged in healthy eating behaviours, although this information was not directly collected.

Finally, participants were asked if they would enjoy being part of a group forum whereby they could support each other and share ideas. Participants in both groups were extremely supportive of the group support. One individual in PPI session 1 explained,

> "I think the support side of things is really crucial as well, because it's all very well to say that you're going to do this programme, but having done Weight Watchers, I know that you have weeks where you have bad weeks and you do put on, or you do maintain, you don't lose weight and going every week and having someone to say, "Right, okay, so what did you do differently this week? Why did you put on weight?" Actually, having somebody to talk through with you personally makes a massive difference and also just having a little talk about whatever it is."

Similarly, women in the second session said, "If I'm about to throw the towel in and everyone can go, 'No'" and, "You've definitely got to have some support" but "as long as it stays positive and motivational". Two individuals also commented on the types of support provided as one mentioned, "I think you need both [face-to-face and WhatsApp group support]" and another agreed by saying, "I think both. Maybe not every week because obviously are busy but maybe every couple of weeks."

4.3.3 Written Responses

The following section presents the results of the four questions included in section 4.2. In response to the first question, 60% of women highlighted that they would prefer the programme to be as long as possible, 20% did not have a preference and 20% said that a 12-week initial programme would appeal but with the option to extend if it was working well. The second question revealed that 50% of participants would prefer a programme based mainly around exercise, however with a mix of both exercise and nutritional guidance. Thirty percent of participants found an exercise only programme more appealing, whilst 10% mentioned that a program consisting of both exercise and diet would only work if each aspect was introduced at different times. The third question asked women to offer their insights into which area of their lifestyle they would be more likely to change if they were doing little exercise and eating unhealthily. Of the 10 women, 60% said they would be more likely to attempt to exercise more and 40% said they would target their diet. Finally, 70% of participants agreed that it would be too overwhelming to change both their diet and physical activity, however 30% thought it would be possible if the changes were gradual and they were provided with appropriate support.

4.4 Discussion

This is the first study whereby postpartum women have been presented with a proposed lifestyle intervention to understand the best approach to adopt when designing and delivering an intervention in this population, whilst minimising barriers to a healthy lifestyle during this time. The results from Chapter 3 were used to design the first version of the study protocol. The main influences from the findings of Chapter 3 were that women cited a lack of motivation and routine in the postpartum period, which, along with medical complications, prevented them from engaging in a healthy lifestyle during this time. The first version of the protocol included a 12-week intervention as this was thought to allow women sufficient time to incorporate behaviour change strategies into their routine. An element of choice over engaging in a diet or exercise intervention was also included as this was believed to increase autonomous motivation and prevent the enrolment of women into the exercise intervention who may not feel physically ready following childbirth. In this PPI work, women agreed with the barriers cited by women in Chapter 3 (see section 3.4) and detailed no new issues that prevented engagement in healthy eating or physical activity behaviours during and following pregnancy. It was important to get the opinions of these end users so that they would understand the background to the proposed intervention design, and to also make sure that no barriers were overlooked in Chapter 3. Ultimately, these women are the ones engaging with the interventions and, in many cases, much previous work may have been destined to fail (*i.e.* be ineffective in producing successful outcomes) as the study designs were not accepted by the women themselves prior to implementation. Specifically, this lack of formative work may be one of the reasons for the unsuccessful outcomes that are commonly observed following postpartum lifestyle interventions aimed at promoting behaviour change (Heppner et al., 2011; Skouteris et al., 2012; Vesco et al., 2012) and significantly reducing BMI (Østbye et al., 2009; Walker et al., 2012; LeCheminant et al., 2014). The data from the current study were used to develop an updated study design. Tables 4.7, 4.8 and 4.9 detail the approaches that were taken to incorporate the results from the current study into a postpartum lifestyle intervention.

Table 4.7 Incorporation of findings from PPI work into the content of the exercise intervention.

PPI Question	Result	Incorporation
Setting?	Outside	Walking is included in the exercise program.
Group/individual?	Group	Whilst it is not possible to design a group-based exercise program due to logistical reasons (*e.g.* location, timings etc.), a WhatApp group is included to encourage group support.
Baby inclusion/exclusion?	Mixed opinions	Women will be able to walk and/or complete circuit sessions with/without the baby.
Time of day?	Mixed opinions	Women will be encouraged to exercise at a time suitable to them and, if necessary, circuit sessions can be shortened to fit into women's days.
Strength/aerobic based?	Combination	A walking program and bodyweight style circuit sessions will be included in the design.
Intensity of exercise?	Gradual increase and Individualised	The exercise program is individualised such that daily step goals in each block of the intervention will target a 10% increase from the previous block. Women will be provided with different difficulty options for each of the exercises included in the circuit sessions, such that the sessions will be individualised. Women will be encouraged to complete as many sets as possible, with the target of increasing sets and reps throughout the intervention at a pace that suits each woman.

Table 4.8 Incorporation of findings from PPI work into the content of the dietary intervention.

PPI Question	Result	Incorporation
Record food by weighing/food diary/phone app?	App	Intake24 application will be utilised to record dietary intake.
Quick recipe ideas useful?	Yes	Quick recipe ideas will be provided throughout the intervention through the WhatsApp group. Women will also be encouraged to share recipe ideas with each other.
Nutritional advice required?	Yes	Nutritional advice will be provided throughout the dietary intervention, including education on food labels and healthy meal/drink swaps.

Table 4.9 Incorporation of findings from PPI work into the study design.

PPI Question	Result	Incorporation
Weighed at different points or start and end?	Weighed at different points	Women will be weighed at seven time points (every 3-4 weeks) throughout the program.
Would motivational texts be useful?	Mixed opinions, phone calls suggested	Motivational texts will be sent to participants throughout the intervention, with the option of arranging a telephone call if required.
Is 4 weeks sufficient time to gain a true representation of your current lifestyle?	Yes	A 4-week tracking period will be included to assess women's lifestyle prior to commencing the intervention.
Would you like to be given the choice of taking part in a diet or exercise program?	PPI1- yes; PP12- majority yes, some participants recognised that both diet and exercise required improvement so would not mind if they were assigned to a program	Women will be given the choice of whether to engage in a diet or exercise program.
Would you enjoy a group forum where you could support each other and share ideas?	Yes	A WhatsApp group will be included whereby women in each of the interventions will be able to support each other and useful links, ideas and recipes will be shared.
Would you prefer a 12 or 16 week program?	60%, as long as possible; 20%, no preference; 20%, option to extend an initial 12-week program	A 12-week intervention will be delivered, with a 4-week follow-up period.
Would you prefer to engage in a diet or exercise program?	50%, mainly exercise based but with a focus on both exercise and diet; 30% exercise only; 10%, both diet and exercise would only work if introduced at different times	Given the split in findings, a choice between engaging in a diet or exercise intervention will be provided.
If you were eating unhealthily and doing very little exercise, would you be more likely to change your diet or increase activity levels?	60%; exercise, 40%; diet	Given the split in findings, a choice between engaging in a diet or exercise intervention will be provided.

Would it be too overwhelming if you were to attempt to change both your diet and physical activity?	70%, yes; 30%, possible if changes were gradual and appropriate support was provided	Participants will be asked to select to focus on either diet or exercise to prevent women feeling overwhelmed when attempting to change both aspects.

4.5 Conclusion

In summary, it was possible to incorporate all but two of the suggestions made by women in the PPI sessions into the final study design. Due to logistical issues, group exercise sessions could not be included, and whilst the majority of women wished to extend the intervention if it was going well this was not possible due to the constraints of my PhD timetable. Strategies to encourage group-based support (*i.e.* WhatsApp group) were, however, embedded into the final intervention protocol.

Chapter 5: The Effects of Exercise and Dietary Interventions in Overweight and Obese Postpartum Women on Weight Management and Health[1]

5.1 Introduction

In recent years, women of reproductive age represent a sub-population with one of the highest increases in obesity rates (NCD Risk Factor Collaboration, 2016). In most developed countries, over half of the women of childbearing age are either overweight (BMI 25-29.9 $kg \cdot m^2$) or obese (BMI > 30 $kg \cdot m^2$) (NHS Digital, 2017). Furthermore, women who enter pregnancy as overweight or obese often experience excessive GWG and prolonged PPWR (Deputy et al., 2015; Kirkegaard et al., 2015), which results in elevated interpartum BMI and women entering subsequent pregnancies with higher BMI's (Kirkegaard et al., 2015). It is crucial that postpartum lifestyle interventions are delivered to encourage weight loss management, and interrupt this pattern of compounding weight gain through the childbearing years, as the negative consequences of an elevated BMI are well documented (World Health Organisation, 2020a). However, despite the fact that the postpartum period has been identified as a 'teachable moment' whereby women are motivated to engage in risk-lowering health behaviours (e.g. healthy eating, physical activity engagement) to benefit both their own and their baby's health (Dinsdale et al., 2016), many previous lifestyle interventions delivered to overweight and obese women during this time have proven unsuccessful in promoting healthy behaviour change (Heppner et al., 2011; Skouteris et al., 2012; Vesco et al., 2012) and producing significant reductions in post-intervention weight (Østbye et al., 2009; Walker et al., 2012; LeCheminant et al., 2014). Methodological issues, such as issues with external validity and lack of long-term follow-ups, and a lack of formative work completed prior to the design and delivery of lifestyle interventions, may explain these observed unsuccessful post-intervention outcomes. The first postpartum period can also be viewed as the pre-conception period of a subsequent pregnancy and strikingly, previous work has identified a 264% increase in the risk of childhood obesity when mothers have obesity prior to conception (Heslehurst et al., 2019). Therefore, if we, as a society, are going to interrupt the current intergenerational cycle of obesity (Ma & Popkin, 2017), then work is urgently required to identify the key components of postpartum lifestyle interventions that encourage more successful weight loss and health outcomes than have been seen previously. In this thesis, two levels of formative work have been completed. Initially, semi-structured interviews (Chapter 3) were conducted to understand perceived barriers to

[1] This intervention is an initial, small-scale study which will be scaled up in the future.

healthy eating and exercise during and following pregnancy in overweight and obese postpartum women. A lifestyle intervention was then developed, which aimed to mitigate these perceived barriers to a healthy lifestyle in the postpartum period, which was presented to women that took part in the PPI sessions detailed in Chapter 4. Specifically, women in the PPI sessions were asked to offer their opinions on the proposed lifestyle intervention and were asked to detail aspects of a lifestyle intervention that they deemed to be important in encouraging successful post-intervention outcomes (*i.e.* significant reductions in weight and improvements in health). The findings from Study 1 and 2 (Chapters 3 and 4) were combined with knowledge of existing literature to develop a co-designed, self-selected, lifestyle intervention strategy. Therefore, the aims of the current study were to:

1) Investigate the effect of a self-chosen exercise or dietary intervention on primary outcomes of postpartum weight and BMI.
2) Investigate the effect of an exercise or dietary intervention on body composition and metabolic health.
3) Investigate the effect of an exercise or dietary intervention on exercise and dietary behaviours.
4) Investigate the effect of an exercise or dietary intervention on emotional health and wellbeing.

5.2 Methodology

5.2.1 Recruitment

Following ethical approval through the National Research Ethics Service (NRES), recruitment of overweight and obese postpartum women was completed through various avenues; radio adverts, posters displayed on social media platforms (e.g. Twitter and Facebook) and through attending mother and baby groups. The inclusion criteria was: BMI $\geq$ 25 $kg \cdot m^{-2}$, age $\geq$ 18 years, English speaker, any socioeconomic background, any ethnicity, 6 weeks to 1 year postpartum (following physician's approval to return to exercise) at time of study enrolment, singleton pregnancy, first pregnancy, any dietary plans, breastfeeding/formula feeding and own a smartphone. Participants were excluded from the study if they had a clinical diagnosis of depression or postnatal depression, were enrolled on another weight loss programme, were consuming weight loss tablets or supplements, had heart, liver or chronic renal disease, had a clinical diagnosis of type 2 diabetes mellitus, consumed excessive amounts of alcohol (regularly drinking more than 14 units a week), were actively trying for another baby or planning a pregnancy in the next 6 months and had experienced a stillbirth. Furthermore, participants were excluded if they had any health conditions that affected physical activity engagement or were on any medication that affected their ability to exercise and/or follow a healthy eating programme.

5.2.2 Sample Size Calculation

An estimation of sample size was conducted using a statistical power calculation based on the research by Huseinovic et al. (2016). The intervention utilised in the Huseinovic et al. (2016) paper was identified as the most similar design to that of the current study. However, whereas Huseinovic et al. (2016) included a dietary intervention group and a control group, the current study design included both dietary and exercise intervention groups. The calculation was conducted to estimate the number of participants required to identify significant differences in reduction in body weight from baseline to post 16 weeks intervention in overweight and obese postpartum women. The sample size estimation was conducted using an online calculator (MGH Biostatistics Center). Based on an α prior level of 0.05 (two-sided), a standard deviation of the outcome variable of 3.5 kilograms, associated power of 0.9 (Pβ), and a minimal detectable difference in the reduction in body weight from baseline to post-intervention of 6.1 kilograms ($p<0.001$; Huseinovic et al., 2016), an estimated sample size (n) of 18 was calculated, with a 93% probability that a significant treatment difference would be detected in the dietary intervention group at the specified α level. When adjusted for dropout rates observed in similar interventions in overweight and obese postpartum women (7/54 participants = 12.96% drop out rate; Huseinovic et al., 2016), an estimated sample size of 21 was calculated for the dietary intervention group. Given that participants were given the choice of which intervention to engage with and equal intervention group sizes may not be achieved a total study cohort of 42 participants was estimated, regardless of total participant in each of the nutritional and exercise intervention groups. In the situation where study recruitment was not as successful as initially anticipated, a target 75% of 42 (n = 32) was set.

5.2.3 Research Design

Data collection was completed between August 2019 and June 2020. Written informed consent was obtained at the first visit. A schematic detailing the timeline and study procedures is displayed in Figure 5.1. The study lasted for 20 weeks: the first four weeks of the study tracked habitual, free-living activity; the interventions lasted 12 weeks, between weeks 4 and 16; and the last four weeks of the study tracked habitual, free-living activity and acted as a legacy follow-up. A control group was not included in the study design because, from an ethical standpoint, it could be argued that public health researchers have an obligation to avoid exploiting their subjects, and that this obligation implies duties to protect subjects' rights and welfare (Miller & Brody, 2002; Morreim, 2005). Specifically, exploitation may occur when subjects do not receive the fair share of the benefits of research (Resnik, 2003), and many believe that investigators who provide subjects with less than the best available care during a research study could be violating their responsibility to promote the health of these individuals (Resnik, 2008). Therefore, the inclusion of a control group who received little or no lifestyle advice may be deemed as ethically unsound. Previously, researchers who have provided control participants with some level of treatment have identified similarities between the intervention and control group as a reason for non-significant findings following a postpartum exercise intervention (LeCheminant et al., 2014). Furthermore, whilst it is recognised that not including a control group does not allow for a comparison between treatment and non-treatment groups at each data collection visit, the tracking period was included (and the four-week duration confirmed by PPI participants as a sufficient time to obtain a true insight into free-living activities) which allowed for a baseline understanding of pre-intervention lifestyle behaviours. As such, a quasi-experimental design was adopted, and women acted as their own controls for the first four weeks of the study.

Each participant was expected to attend the laboratories at Nottingham Trent University Clifton Campus on seven occasions, lasting between 30 minutes and 1.5 hours. Participants were given the option to arrange home visits for visits 3-5 if this was more suitable. Data collection took place in the morning for visits 1, 2, 6 and 7. Where possible, morning visits were also arranged at visits 3-5.

5.2.3.1 Visit 1 – Baseline – week 0

Following the completion of all measures, participants were provided with a Fitbit and if necessary, were instructed on how to use it. The Fitbit was worn for the entirety of the study.

At this time participants were encouraged to maintain their current lifestyles. During weeks 1-4 participants were asked to complete four 24-hour food recalls on pre-determined days unknown to the participant. A telephone call was arranged and/or instruction sheet was provided to the participants prior to the first food recall and participants were able to ask any questions through WhatsApp or telephone call whilst completing each of the four food recalls.

5.2.3.2 Visit 2 – Post Tracking – week 4

Following the completion of all measures, each participant watched a short video detailing the exercise and dietary interventions and were free to ask any questions about the structure and delivery of the interventions. Participants were then given 24 hours to choose which intervention they wished to be part of, during which time they were encouraged to make their decision known or were contacted after 24 hours to determine their decision. At this point an information pack detailing the first three weeks of the intervention was sent in the post via 24 hour tracked delivery and participants were added to a prior created WhatsApp group related to either the dietary or exercise intervention.

5.2.3.3 Visits 3-5 – Intervention – weeks 4-16

During weeks 7, 10 and 13 participants were provided with a supplementary dietary or exercise information pack to utilise for the next 3 weeks and were given the opportunity to discuss any queries and issues.

5.2.3.4 Visit 6 – Post intervention – week 16

Participants were not provided with any new intervention information, but were encouraged to maintain or further improve adherence to the programme for the final 4 weeks. Following the visit, participants were withdrawn from the WhatsApp group and did not receive any text messages or phone call support. The time between the post-intervention and follow-up visit was used to track new free-living behaviour.

5.2.3.5 Visit 7 – Follow-up – week 20

During week 20, participants were invited to the laboratory and all measures (minus collection of blood for glycated haemoglobin (HbA1c) analysis) were repeated. Upon completion of all tests and protocols participants were provided with the information packs from the opposing intervention and were formally debriefed.

5.2.3.6 Intervention Details

The dietary intervention was split into four blocks of 3 weeks. New information was provided every 3 weeks and it was expected that participants combine all the information gained to make gradual improvements to their diet over the course of the 12 weeks. The overall aim of the intervention was to be eating a healthy, balanced diet in line with government recommendations. The first 3 weeks (weeks 5-7) focused on reducing portion sizes and healthy snacking. Part 2 (weeks 8-10) focused on understanding food labels and substituting regular foods for low fat and low sugar alternatives. Part 3 (weeks 11-13) introduced the Eatwell guide and encouraged healthy lunch and dinner swaps, and part 4 (weeks 14-16) focused on healthy breakfast and drink swaps (see Appendices 5C-5F for dietary information packs). Further information and advice was also provided at various points throughout the intervention, delivered at individual visits and through the WhatsApp group.

The exercise intervention was also split into four blocks of 3 weeks. The programme was of a progressive nature whereby the duration and intensity of the exercise gradually increased throughout the 12 weeks. The overall aim by the end of the programme was to be exercising at a moderate to high intensity for a total of 150 minutes a week, in line with government recommendations. The first 3 weeks focused on increasing total daily steps from the previous 4 weeks (tracking phase) and introducing daily physical activity swaps. Weeks 8-10 (part 2) focused on increasing total daily steps as well as completing pre-designed at home circuit sessions. Parts 3 (weeks 11-13) and 4 (weeks 14-16) encouraged increased total daily steps and increased duration and intensity of the circuit sessions (see Appendices 5G-5J for exercise information packs). At weeks 11-13, participants were provided with bonus circuit sets and verbally encouraged to complete these if physically able. Pre-designed videos and information sheets detailing the correct technique for each exercise were provided. Further information and advice was also provided at various points throughout the intervention, delivered at individual visits and through the WhatsApp group. Participants were encouraged to use the Fitbit to self-monitor their own behaviours.

In both interventions, participants were encouraged to use the WhatsApp group as a means to support each other and, for example, arrange group exercise meet-ups and walks. Participants were also encouraged to self-weigh at home whenever convenient. At each intervention visit, participants were also encouraged and supported to set new behaviour change and weight loss goals.

5.2.3.7 Text Messages

Throughout weeks 5-16 of the intervention, participants received text messages and had the option to arrange telephone consultations, if deemed necessary. Four text messages per week were delivered to the participants; the first three were motivational and contained key lifestyle types, the fourth text asked participants to rate (on a scale of 1-5) commitment to the intervention during the previous week. Participants were asked to reply 'YES' if they required a follow-up telephone consultation.

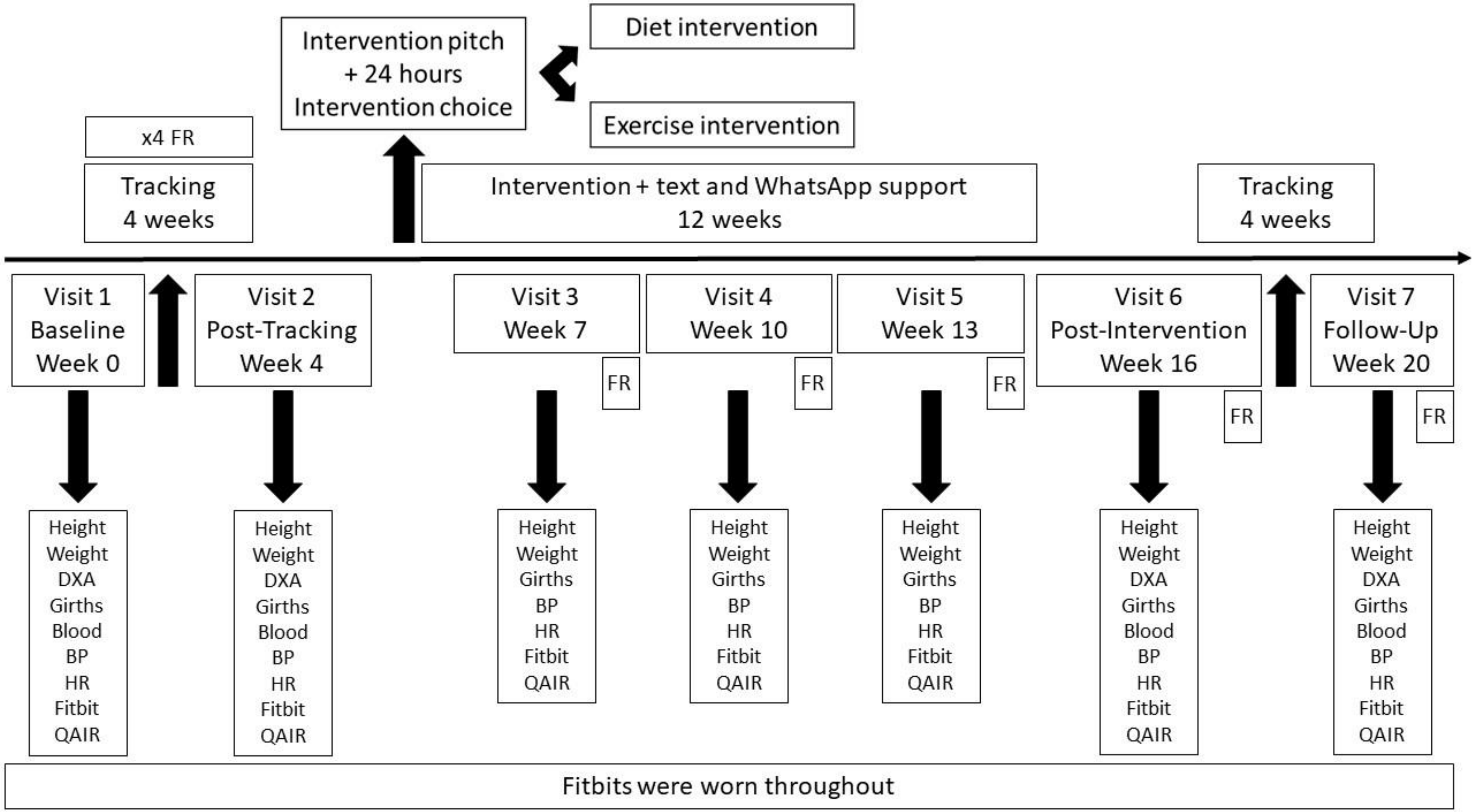

Figure 5.1 Study schematic [version 2 following the public and patient involvement from Study 2, Chapter 4]. Abbreviations: DXA – Dual-Energy X-Ray Absorptiometry; BP – blood pressure; HR – heart rate; QAIR – questionnaires; FR – food recall.

5.2.4 Research Protocols

5.2.4.1 Primary outcome measures

5.2.4.1.1 Height

Height was recorded to the nearest 0.001m at the baseline visit by a stadiometer.

5.2.4.1.2 Weight

Weight was measured to the nearest 0.1kg by an electronic scale (Adam GFK150), with women in light clothing and bare feet.

5.2.4.1.3 BMI

BMI was calculated through the division of weight (kg) by height (m^2).

5.2.4.2 Secondary outcome measures

5.2.4.2.1 Dual-Energy X-ray Absorptiometry Scan

A Dual-Energy X-ray Absorptiometry (DXA) scan (GE Healthcare) was used to measure whole body soft tissue composition and bone mass (Kelly et al., 1998; Laskey, 1996). Two x-ray attenuations pass through the body and can be used to calculate the mass of different materials given simple algebra and the physical properties of said materials (Blake, Wahner, & Fogelman, 1999). Given its unique ability to simultaneously measure, fat mass (FM), lean mass and bone, DXA is becoming more popular as a technique to measure the efficacy of exercise and diet interventions (Shepherd, Ng, Sommer, & Heymsfield, 2017).

Participants were instructed to lie in a supine position in the middle of the white marked box on the scanner bed. Participant positions were readjusted if necessary, following which two straps were placed around the participant's knees and ankles to ensure the body remained as still as possible throughout the duration of the scan. Participants were asked to place their hands by their sides with palms flat on the bed and if necessary, they tucked their thumbs under their buttocks to ensure the full body was within the scanning area/white box. Food and fluid intake are known to induce changes in the mean estimates of total and regional body composition (Nana, Slater, Hopkins, & Burke, 2013), therefore participants were asked to arrive in the lab fasted (having consumed no food or caffeine in the previous 12 hours) and were instructed to void the bladder prior to the DXA scan.

Normative reference values have been created for use with GE-Healthcare DXA systems (Imboden et al., 2017), which were used in the comparison and analysis of the results from the present study. The following body composition variables, known to influence health, were included in the analysis; percentage body fat, trunk percentage fat, legs percentage fat, android/gynoid (A/G) ratio, trunk/limb ratio, trunk/leg ratio and fat mass index (FMI). FMI was calculated by dividing total FM by height squared, which aids in the interpretation of body composition as, unlike BMI, it is not confounded by lean tissue (Kelly et al., 2009). Regional FM distribution is also an important indicator of any cardiovascular and metabolic health complications (Glickman, Marn, Supiano, & Dengel, 2004; Wiklund et al., 2008), specifically the A/G, trunk/limb and trunk/leg ratios have been shown to be reliable markers of lipodystrophy and display good correlation with dyslipidaemia and insulin resistance (Aasen, Fagertun, & Halse, 2006; Min & Min, 2015).

5.2.4.2.2 Girths

Participants were asked to wear tight fitting trousers (*e.g.*, leggings) or shorts and a t-shirt for the collection of girth measurements. Throughout the collection of girth measurements, participants were asked to stand in a relaxed, neutral stance.

- To collect a waist measurement, participants were initially asked to locate the narrowest part of the own waist, and a check was performed if required. Participants were asked to hold one end of the tape measure and the other end was walked around their body.
- To collect a hip measurement, participants were initially asked to identify the widest part around the buttocks, and adjustments were made if required. Participants were asked to hold one end of the tape measure and the other end was walked around their body.

- To collect an upper arm measurement, participants were initially asked to identify the widest part between the indent in the elbow and the top of the shoulder, and adjustments were made if required. Participants were asked to hold their arm away from the body to allow the tape measure to be passed around the arm. The reading was taken with the arm relaxed.
- A bust measurement was taken across the widest part of the bust, following identification by the participant. The participant was asked to hold the tape measure on the bust and the other end was passed around the body.
- Participants were asked to stand in an anatomical position with the legs slightly apart to allow the identification of the widest part of the thigh and the top of the kneecap. The widest part of the calf was also recorded in the same position.

5.2.4.2.3 Blood Sample

A fasted fingertip blood sample was obtained using capillary sampling, to analyse metabolic markers of health. Analysis of total cholesterol (TC), high-density lipoprotein cholesterol (HDL), low-density lipoprotein cholesterol (LDL), triglyceride (TG) and HbA1c was completed using a Pentra C (Horiba) Analyser, using commercially available analysis kits. Where necessary, and according to manufacturer guidelines, samples were stored at -20°c or -80°c. Samples were stored within one hour of sampling. For determination of random glucose, a 25µl fingertip sample was collected using a 25µl plain pre-calibrated glass pipette and immediately deproteinised in 250µl of 2.5% ice cooled perchloric acid in 1.5ml plastic vials and centrifuged at 7000rpm for 4 minutes. Glucose concentrations were determined in duplicate using a commercially available kit (GOD-PAP method, GL 2610, Randox, Ireland).

5.2.4.2.4 Blood Pressure

Blood pressure (BP) was recorded in a seated position using an electronic BP monitor (Boso Medicus Smart), with the participant's arm placed on the upper leg. In line with recommendations, an average of at least two readings was taken at an interval of at least one minute apart (Pickering et al., 2005). If the difference between the two readings was more than 5 mmHg, one or two further readings were taken and an average of the multiple readings was used.

5.2.4.2.5 Heart Rate

Participants were fitted with a heart rate (HR) monitor (Polar T31) prior to completing the questionnaires, and the lowest value during this time was recorded.

5.2.4.2.6 Fitbits

Participants were provided with a Fitbit at visit 1 and were encouraged to wear it for the entirety of the study. Following each visit, participants were asked to (or it was completed on their behalf) update the body mass in the characteristics section of the Fitbit application, such that calorie expenditure was adjusted accordingly. Throughout the intervention, participants in the exercise group were encouraged and supported to set their own physical activity related goals related to the Fitbit data (*e.g.*, 10,000 steps per day). Participants in the exercise group were also provided with individualised advice relating to increasing daily steps by 10% from the average in the previous block. Although participants in the diet group were provided with a Fitbit, personalised goals were not set with them.

5.2.4.2.7 Questionnaires

5.2.4.2.7.1 Participant Demographics Questionnaire

Each participant completed a demographics questionnaire (Appendix 5K) that contained questions regarding date of birth, support levels, ethnicity, occupation, maternity leave status, highest educational qualification, breastfeeding status, and if any advice on diet or physical activity had been received during and/or following pregnancy. Participants were also asked to provide information regarding the baby's date of birth, mode of delivery and numbers of days spent in hospital before and after the birth.

5.2.4.2.7.2 Short-Form 36 Questionnaire

Participants were asked to complete the Short-Form 36 (SF-36) questionnaire to assess eight domains of health status: physical functioning, role limitations due to physical health, role limitations due to emotional problems, energy/fatigue, emotional wellbeing, social functioning, pain and general health status (Appendix 5L). The sum score in each domain ranges from 0 to 100; a higher score indicating better health status (Da Costa, Dritsa, Rippen, Lowensteyn, & Khalifé, 2006).

5.2.4.2.7.3 Godin-Shephard Leisure-Time Physical Activity Questionnaire

The Godin-Shephard Leisure-Time Physical Activity Questionnaire was administered to assess physical activity levels (Appendix 5M). At the time of questionnaire development, reliability for the strenuous activity and total leisure-time physical activities score were 0.94 and 0.74 (Godin & Shephard, 1985). Activities are split into three sub-categories: "strenuous", "moderate" and "light". Activities performed for more than 15 minutes in a week are multiplied by their coefficients to calculate energy expenditure (metabolic equivalent (MET)). MET intensity values are represented as follows; strenuous activities: 9 METs, moderate activities: 5 METs, and light exercises: 3 METs. The amount of oxygen consumption while seated at rest (3.5ml O_2 per kg body weight) is multiplied by total minutes to calculate MET. Increasing scores are, therefore, associated with increasing number of exercise behaviours and the overall score provides a reference regarding the contribution of physical activity to health. An activity score of 24 units or more is classified as active (substantial benefits), a score of 14-23 is moderately active (some benefits) and 13 units or less corresponds to inactivity (low benefits) (Godin, 2011).

5.2.4.2.7.4 Three Factor Eating Questionnaire

The revised 18-item Three Factor Eating Questionnaire (TFEQ) was completed by all participants and used to assess restrained eating (conscious restriction of food intake to control body weight or encourage weight loss), uncontrolled eating (tendency to overeat due to a lack/loss of control over intake accompanied by increased feelings of hunger) and emotional eating (unable to resist emotional cues) behaviours (Appendix 5N). For all responses an absolute score was obtained from the four-point scoring scale provided. The degree of expression (0-100%) was determined for each behaviour, with higher values indicating more pronounced expression of that behaviour (Anglé et al., 2009).

$$(S - L)/R\_S \text{ X } 100$$

In the formula, S = raw score, L = lowest possible raw score and R_s = possible raw score range.

The construct validity of the TFEQ has previously been assessed in overweight and obese individuals (Karlsson, Persson, Sjöström, & Sullivan, 2000). The factor structure of the original 51-item questionnaire was not replicated in the population, therefore the revised 18-item instrument was created. This version was used in the current study.

5.2.4.2.7.5 Pittsburgh Sleep Quality Index

To assess sleeping habits, we used the Pittsburgh Sleep Quality Questionnaire (PSQI), a highly valid and reliable instrument designed specifically to assess sleep quality (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) (Appendix 5O). The questionnaire is comprised of 19 questions and seven major components. Each component is scored from 0 to 3 points, where a higher score denotes worsening issues in the following order: 1) subjective sleep quality, 2) sleep latency (≤15 min to >60 min), sleep duration (>7 hr to <5 hr), 4) sleep efficiency (≥ 85% to <65%hr sleep/hours spent in bed), 5) sleep disturbances (not in the last month to ≥ 3 times per week), 6) consumption of sleeping medication (none to ≥ 3 times a week) and 7) daytime dysfunction (no issues to very common issue) (Buysse et al., 1989). A scale ranging from 0 to 21 points was then created from the sum of seven components. For the purpose of the current study, the results were dichotomised into two categories: 1) ≤ 5 (good sleep quality) vs. 2) > 5 (poor sleep quality), as proposed by Buysee et al. (1989).

5.2.4.2.7.6 Edinburgh Postnatal Depression Scale

The Edinburgh Postnatal Depression Scale (EPDS) is a 10-item self-report scale to screen for postnatal depression (Appendix 5P). All participants were asked to complete the questionnaire and were encouraged, as per the questionnaire guidelines, to seek advice from medical professionals if a score of 10 or above was calculated at any of the seven visits. Following extensive pilot interviews, the EPDS was previously validated in 84 mothers using the

Research Diagnostic Criteria for depressive illnesses attained from Goldberg's Standardised Psychiatric Interview (Cox, Holden, & Sagovsky, 1987). The EPDS showed satisfactory specificity and sensitivity, and also demonstrated high levels of sensitivity in detecting changes in the severity of depression over time.

5.2.4.2.8 Food Recalls

Participants received four requests during the tracking period and one request in the week preceding each study visit in the intervention period asking them to complete a 24-hour food recall. They were provided with individual login details and instructions as to how to complete the first recall (and were given the opportunity to ask any questions over the phone), as well as being issued with a list of reminders prior to each recall (see Appendix 5Q). Participants were asked to include all of the food and drink that they had consumed in the period from midnight-midnight on the previous day. Participants were unaware of the days that they would be asked to complete the food recall, but all days were weekdays. Participants were also given the opportunity to utilise Intake 24 at any time during the intervention period; feedback regarding total calorie and macronutrient intake was provided thereafter.

5.2.4.2.9 Rationale for Secondary Measures

DXA is a gold standard method for assessment of body composition (Colley et al., 2015), and is a valid and reliable measure for assessment of total fat mass in adult populations (Mei et al., 2002). However, few investigations have utilised this method to explore body composition in postpartum women enrolled in lifestyle interventions (Bertz et al., 2012). More postpartum studies have used, for example, bioelectrical impedance to assess body composition (Huseinovic et al., 2016; Keller et al., 2014; Lee, McInnes, Hughes, Guthrie, & Jepson, 2016), yet bioelectrical impedance is known to overestimate FFM and seems too imprecise for use at an individual level because of large limits of agreement regarding both change over time and absolute comparisons when compared to reference methods, specifically DXA and doubly labelled water methods (Ellegård, Bertz, Winkvist, Bosaeus, & Brekke, 2016).

The collection of girth measurements, blood samples (for analysis of cholesterol, triglycerides and fasting blood glucose) and BP allows for a comprehensive understanding of cardiometabolic risk and any change in measures of risk throughout the intervention period. Furthermore, despite an elevated postpartum BMI being a well-known risk factor for the development of type 2 diabetes mellitus (Benjamin, Winters, Mayfield, & Gohdes, 1993; Henry & Beischer, 1991; Kaufmann, Schleyhahn, Huffman, & Amankwah, 1995), little is known about the metabolic benefits of small weight changes within the context of diabetes prevention following pregnancy (Lim, Versace, O'Reilly, Janus, & Dunbar, 2019). Therefore, the collection of blood for analysis of HbA1c allowed for a much-needed primary insight into the effects of a postpartum lifestyle intervention on long-term glucose control in this population of overweight and obese women.

Akin to work completed by Evenson (2011) who aimed to understand change in physical activity levels through pregnancy and into the postpartum period using both objective and subjective measures, it was deemed important to also collect both measures of physical activity and dietary intake in the current study. Specifically, it is known that recall bias of physical activity can cause potential mismeasurement (Evenson 2011), but there is also the possibility that women may fail to wear the Fitbit for periods of time throughout the intervention. Furthermore, despite being sent reminders, it is likely that women will fail to complete all food recalls. Therefore, the inclusion of the TFEQ and Godin questionnaires at each visit allows for a guaranteed subjective insight into any changes in eating behaviours and physical activity engagement, whilst also obtaining important objective insights throughout the study period.

The SF-36 questionnaire has previously been validated in postpartum (Bahrami, Karimian, & Bahrami, 2014) and overweight and obese (Corica et al., 2006) populations. Engagement in physical activity has previously been shown to increase wellbeing at three to 12 months after pregnancy (Bahadoran et al., 2014) and results of a meta-analysis showed that physical activity is a safe strategy to encourage better psychological wellbeing and reduce depressive symptoms in the postpartum period (Poyatos-León et al., 2017). Furthermore, high postpartum diet quality is known to be linked to improved quality of life (Hagberg et al., 2019). However, despite the well-established links between engagement in postnatal physical activity and healthy dietary practices and improved wellbeing, few studies have utilised the SF-36 to assess any change in wellbeing and quality of life throughout the course of a postpartum lifestyle intervention (Hagberg et al., 2019), and therefore further work is required.

Lack of sleep duration is associated with several chronic conditions, including type 2 diabetes, depression, various forms of cancer, as well as impaired quality of life, impaired cognitive function, and increased mortality (Colten and Altevogt, 2006). Compared to non-postpartum counterparts, postpartum women are known to get one to two fewer hours of sleep per night (Thomas & Foreman, 2005), but postpartum sleep quality is known to be higher in women who engage in $\geq$150 minutes a week of physical activity (Matenchuk & Davenport, 2020). Furthermore, a U-shaped association exists between sleep duration and diet quality in the general adult population (Grandner, Jackson, Gerstner, & Knutson, 2013; Kim, DeRoo, & Sandler, 2011), and postpartum women are known to have poor diet quality in the five years following childbirth (Xiao et al., 2016). Therefore, the inclusion of the PSQI allowed for insights into the effect of engagement in a dietary or physical activity intervention on postpartum sleep quality.

5.2.5 Statistical Analysis

Shapiro-Wilk tests were conducted to test for normality. In line with recommendations by Sinclair, Taylor, and Hobbs (2013), adjustments for multiple comparisons were not made as it is believed that this leads to fewer errors of interpretation. Two factor mixed model ANOVA was conducted on all outcomes measures except HbA1c: providing the main effect of time, the main effect of group and the interaction between time and group. A repeated [one factor] ANOVA (or Friedman's test) was conducted on all outcome measures except blood and DXA: providing a within group comparison across time. Paired samples t-tests (or Wilcoxon Signed-Rank tests) were used to conduct post hoc comparisons. For paired sample tests, the effect size (Cohen's *d*) of all significant differences was calculated using group pairings. For paired sample t-tests, the effect sizes were interpreted using the following thresholds; <0.2 = trivial effect; 0.2-<0.5 = small effect; 0.5-0.8 = moderate effect and >0.8 = large effect (Cohen, 1992). For Wilcoxon Signed-Rank tests, the effect sizes were classified according to Field (2018) as follows; 0.2-0.5 = small effect, 0.5-0.8 = medium effect, $\geq$0.8 = large effect. Due to the laboratory closures caused by the pandemic, there was insufficient DXA and blood data to warrant any within group analysis. As such, these data were only included in the mixed model analysis. Due to the considerable impact of Covid-19 on the blood sampling aspect of the study, analysis of HbA1c was completed on the combined data set (*i.e.,* all participants - diet and exercise). A paired sample t-test was used to determine the differences between visit 1 and visit 6. Data are presented as mean ± 1SD, using 95% CI unless stated otherwise. SPSS (Version 26, SPSS Inc., Chicago, Il, USA) was utilised for all analysis and accepted significance was set at $p<0.05$.

5.3 Results

5.3.1 Study Participants

Twenty-seven women enrolled in the study; 20 (74%) women completed the full 20-week programme, one woman (4%) completed 16 weeks of the 20-week programme and the remaining six (22%) women withdrew from the study at various points between week 7 and week 15 as shown in Figure 5.2. Ultimately, it was not possible to recruit the number of participants suggested by the sample size calculation due to an eight-month delay in obtaining ethical approval, such that the recruitment period was cut to five months rather than the initial 12-months as originally planned. It was important not to extend recruitment past January 2020 to allow for data collection to be completed in the three-year PhD timeframe.

Participant characteristics are presented in Table 5.1, split into the full group, diet group and exercise group. There were no significant differences in the following baseline characteristics between groups (all $p > 0.05$): age; weight, difference in infant age at enrolment; infant birthweight; number of days spent in hospital prior to and following the birth; maternity leave status; breastfeeding status.

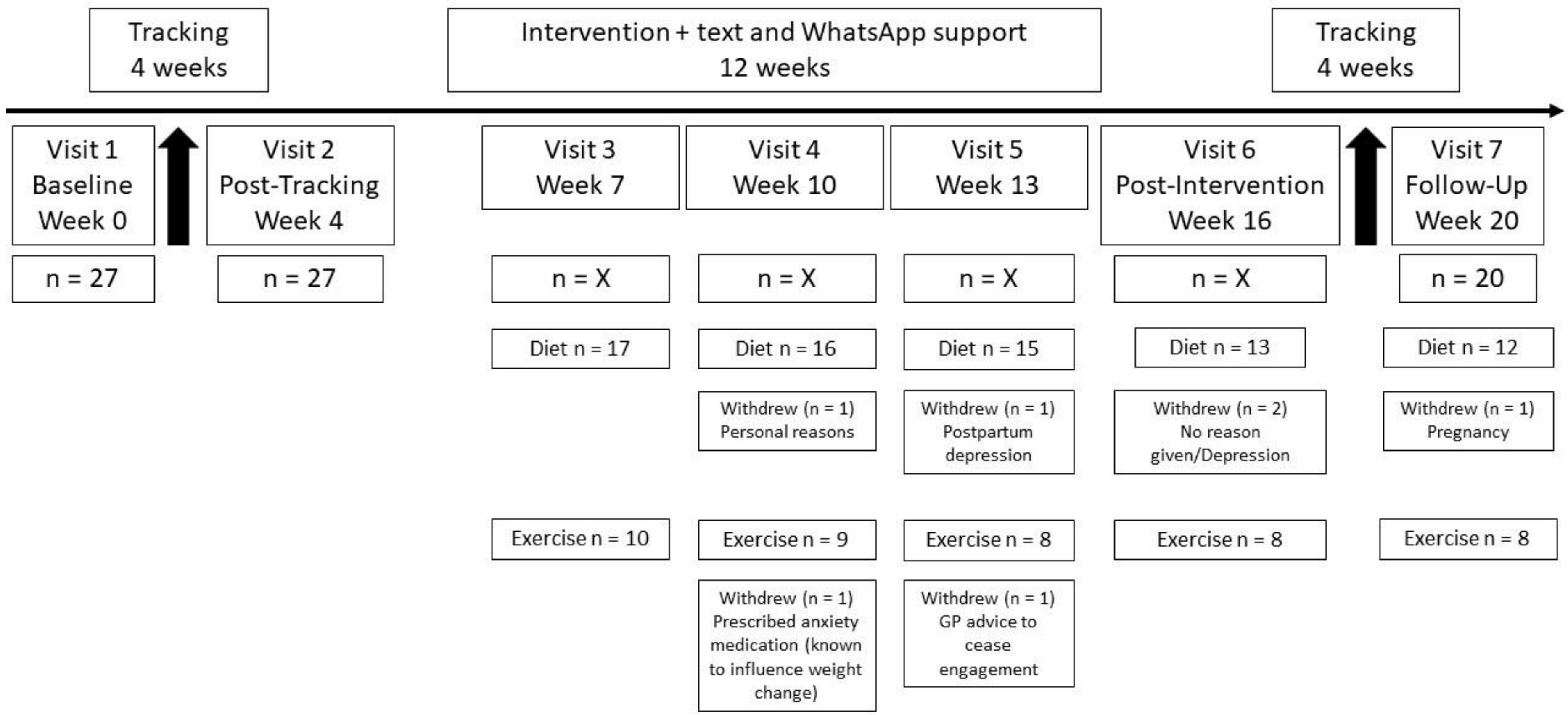

Figure 5.2 Study flowchart detailing participant withdrawals and reasons.

Table 5.1 Participant characteristics at baseline.

Variable	FULL group (*n* = 27)	DIET group (*n* = 17)	EXERCISE group (*n* = 10)
Age (years)	32.21 ± 2.95	32.17 ± 2.19	32.29 ± 4.07
Height (m)	1.64 ± 0.07	1.63 ± 0.07	1.64 ± 0.06
Weight (kg)	80.95 ± 11.09	81.59 ± 10.23	79.87 ± 12.94
BMI ($kg \cdot m^{-2}$)	30.32 ± 4.08	30.79 ± 4.08	29.51 ± 4.16
% (n)- BMI <25$kg \cdot m^2$	7.4 (2)	5.9 (1)	10 (1)
% (n)- BMI 25-29.9$kg \cdot m^2$	40.7 (11)	35.3 (6)	60 (6)
% (n)- BMI 30-34.9$kg \cdot m^2$	33.3 (9)	35.3 (6)	20 (2)
% (n)- BMI >35$kg \cdot m^2$	18.5 (5)	23.5 (4)	10 (1)
Ethnicity, % (n)			
White	88.9 (24)	94.1 (16)	80 (8)
Mixed	3.7 (1)	5.8 (1)	0 (0)
White/Asian	3.7 (1)	0 (0)	10 (1)
Asian/Asian British	3.7 (1)	0 (0)	10 (1)
Education, % (n)			
High school	14.8 (4)	11.8 (2)	20 (2)
College/university	85.2 (23)	88.2 (15)	80 (8)
Maternity leave status, % (n)*			
Yes	88.5 (23)	93.8 (15)	80 (8)
No	11.5 (3)	6.3 (1)	20 (2)
Support, % (n)			
Yes	100 (27)	100 (17)	100 (10)
No	0 (0)	0 (0)	0 (0)
Breastfeeding status, % (n)			
Yes	51.9% (14)	52.9 (9)	50 (5)
No, stopped	37.0% (10)	41.2 (7)	30 (3)
Never	11.1% (3)	5.9 (1)	20 (2)
Infant birth weight (lbs)	7.51 ± 1.05	7.40 ± 0.96	7.69 ± 1.23
Infant age (days)	183.74 ± 96.84	199.76 ± 89.04	156.50 ± 108.12
Mode of delivery, % (n)			
Natural	33.3 (9)	41.2 (7)	20 (2)
C-section	37.0 (10)	35.3 (6)	40 (4)
Forceps	22.2 (6)	17.6 (3)	30 (3)
Ventouse	7.4 (2)	5.9 (1)	10 (1)
Length of hospital stay	3.85 ± 2.54	3.18 ± 2.67	5.00 ± 1.89

Data are presented as mean ± 1SD or percentage (no. of participants). Percentages may not equal 100 because of rounding. Continuous data was analysed with the independent t-test and Mann-Whitney tests. Nominal data was analysed using the χ^2 test, *- one participant was self-employed and unsure when she would return to work, therefore *n* = 26.

5.3.2 Impact of COVID-19

The study was ongoing when the first national Covid-19 lockdown was implemented (March 2020). In order to continue with data collection, the following equipment was left on participants' doorsteps and cleaned between visits; individual study folder containing all questionnaires, BP monitor, HR monitor, tape measure for girth measurements and scales. Of note, the same equipment was used prior to and during the lockdown, as it had been removed from the laboratory prior to university closure. All participants were asked to take a picture of the value on the scales at each visit and send via WhatsApp in an individual message. Participants were provided with an instruction sheet on how to operate the scales, BP monitor, HR monitor and collect girth measurements. Participants were encouraged to ask any questions over WhatsApp/phone call whilst completing the measures inside their homes. Although participants were initially asked to provide girth measurements with the help of a partner, it was decided not to include these measures in the final analysis given the unreliable nature of the data. As a result of the laboratory closure, DXA scans and blood samples were not possible for all participants. As such, data for the primary outcomes (*i.e.*, weight, height and BMI) are available for all participants, whilst data for the secondary outcomes (*i.e.*, DXA, girths, metabolic markers, BP and HR, questionnaires) contain partial datasets as shown in Figure 5.3. Tracking data (*i.e.,* Fitbit and food recall) is available for all participants for the full 20 week study period.

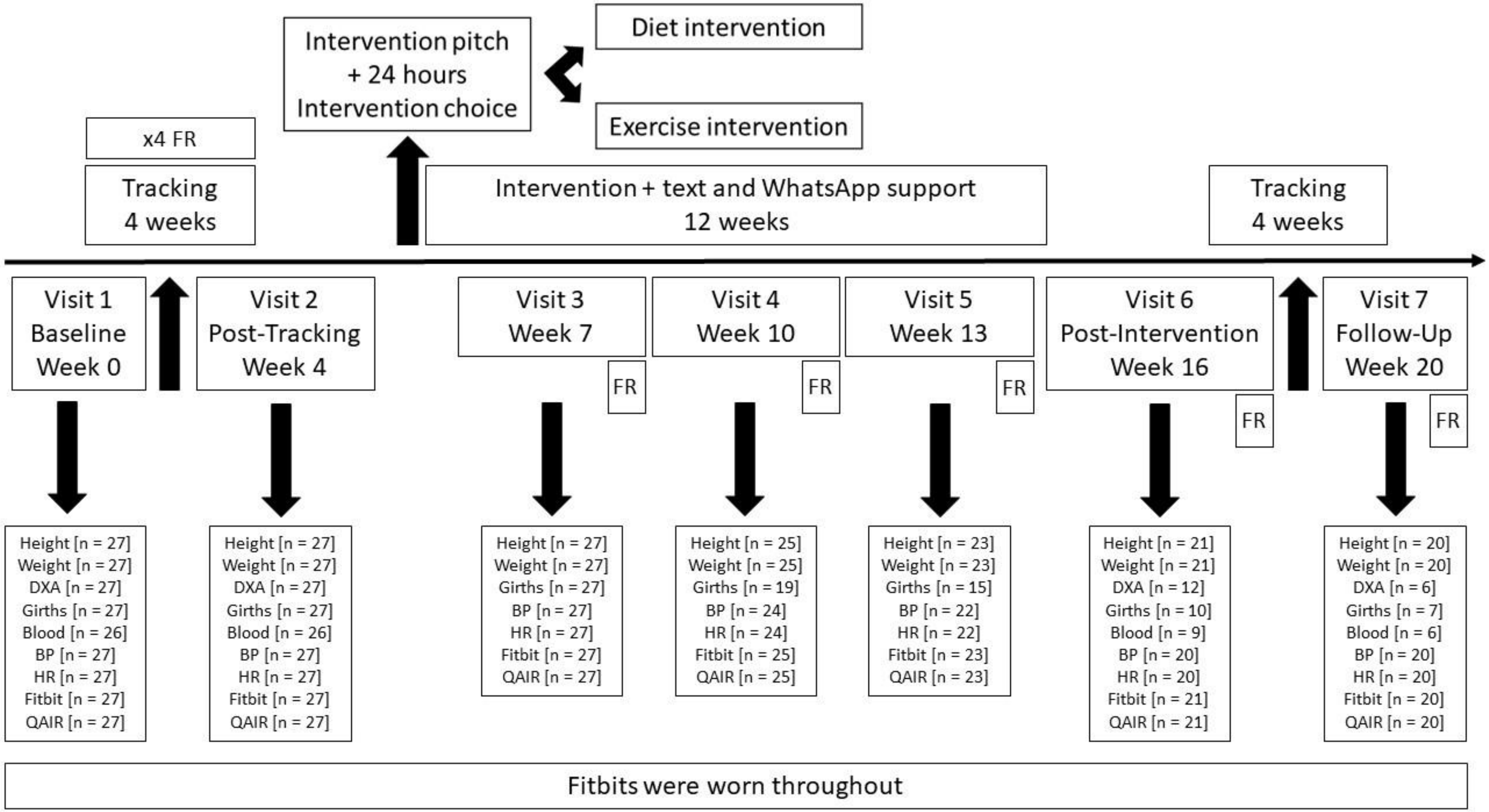

Figure 5.3 Study flowchart detailing collection of primary and secondary datasets at each study visit. Abbreviations: DXA – Dual-Energy X-Ray Absorptiometry; BP – blood pressure; HR – heart rate; QAIR – questionnaires; FR – food recall.

5.3.3 Summary of Main Findings

Given the vast amount of data associated with this study, the main findings are summarised here (Table 5.2) for ease, with more specific details presented in the following sections.

Table 5.2 Summary of the significant findings from each of the primary and secondary outcome measures. Blank rows represent measures without any significant differences.

Variable	Outcome(s)
	Primary outcomes
BMI	**Mixed model**: [Main effect of time] BMI was significantly reduced over time **Within diet**: BMI was significantly reduced over time **Within exercise**: BMI was significantly reduced over time
Weight	**Mixed model**: [Main effect of time] Weight was significantly reduced over time **Within diet**: Weight was significantly reduced over time **Within exercise**: Weight was significantly reduced over time
	Secondary outcomes
DXA	**Mixed model**: [Main effect of time] FFM and FMI were significantly reduced over time **AND** [Group x time interaction] FFM decreased much more in the diet group than in the exercise group [almost no change in the exercise group] FMI decreased in the diet group and increased in the exercise group
Girths	**Mixed model**: [Main effect of time] Hip, waist, thigh and bust girth measures were significantly reduced over time **AND** [Group x time interaction] Bust girths decreased much more in the diet group than in the exercise group [almost no change in the exercise group] **Within diet**: Hip, waist, and bust girths were significantly reduced over time **Within exercise**:
Blood	**Mixed model:**
BP	**Mixed model:** **Within diet**: **Within exercise:**

Resting HR	**Mixed model:** **Within diet**: **Within exercise:**
Fitbit	**Mixed model:** [Main effect of time] Total daily steps, distance, active minutes, and calorie expenditure were significantly increased over time **Within diet**: Total daily steps, distance, and active minutes were significantly increased over time **Within exercise:** Total daily steps and active minutes were significantly increased over time
SF-36	**Mixed model:** [Main effect of time] Physical functioning, energy/fatigue and general health constructs improved over time **AND** [Group x time] Physical functioning increased in both groups but at different rates **Within diet**: Physical functioning, energy/fatigue, pain, and general health constructs improved over time **Within exercise:** Physical functioning improved over time
Godin LTPA	**Mixed model:** [Main effect of time] Leisure-time Physical Activity Score improved over time **Within diet**: Leisure-time Physical Activity Score improved over time **Within exercise:** Leisure-time Physical Activity Score improved over time
TFEQ	**Mixed model:** [Main effects of time] UE, UE%, CR, CR% and EE were improved over time **Within diet**: UE, UE%, CR, CR%, EE and EE% were improved over time **Within exercise:** UE, UE%, CR, CR% were improved over time
PSQI	**Mixed model:** [Main effect of time] Sleep Quality Index was improved over time **Within diet**: Sleep Quality Index was improved over time **Within exercise:**
Food Recalls	**Mixed model:** [Main effects of time] Total daily saturated fat intake worsened over time **AND** [Main effect of group] Protein intake was significantly higher in the exercise group **Within diet**: Calories, fat, saturated fat, protein, and carbohydrate were significantly reduced over time **Within exercise:**

Abbreviations: FFM, fat-free mass; FMI, fat mass index; FM, fat mass; FM%, fat mass percentage; FFM%, fat-free mass percentage; A/G, android/gynoid; TC, total cholesterol; HDL, high-density lipoprotein cholesterol; LDL, low-density lipoprotein cholesterol; TG, triglycerides; HbA1c, glycated haemoglobin; BP; UE, uncontrolled eating; UE%, percentage expression of uncontrolled eating; CR, cognitive restraint; CR, percentage expression of cognitive restraint; EE, emotional eating; EE%, percentage expression of emotional eating.

5.3.4 BMI & Body Composition

5.3.4.1 Primary Outcomes

5.3.4.1.1 BMI

Mixed: There was a significant difference in BMI over time (main effect of time; $F(6,108) = 40.328$; $p = 0.000$) with the data from both intervention groups combined, but no significant difference in BMI between the diet and exercise groups (main effect of group; $F(1,18) = 0.172$; $p = 0.683$) irrespective of measurement time. The pattern of change in BMI was similar [no significant differences] between the diet and exercise groups (group x time interaction; $F(6,108) = 3.120$; $p = 0.059$).

Within: In the diet group, BMI decreased from 30.79 ± 4.08kg/m^2 at baseline to 28.18 ± 3.78kg/m^2 at post-intervention and 27.91 ± 4.04kg/m^2 at follow-up. In the exercise group, BMI decreased from 29.51 ± 4.16kg/m^2 at baseline to 27.74 ± 4.87kg/m^2 at post-intervention and 27.61 ± 4.93kg/m^2 at follow-up. There was a significant effect of time on BMI in the diet ($F(6,66) = 31.452$; $p = 0.000$) and exercise ($\chi^2(6) = 39.275$; $p = 0.000$) group. Figure 5.4 shows the mean (SD) BMI data for both groups at each study visit. Due to the numerous significant [post-hoc] differences between visits for both groups, this information is not denoted on Figure 5.4, instead it is presented in Table 5.3 and 5.4.

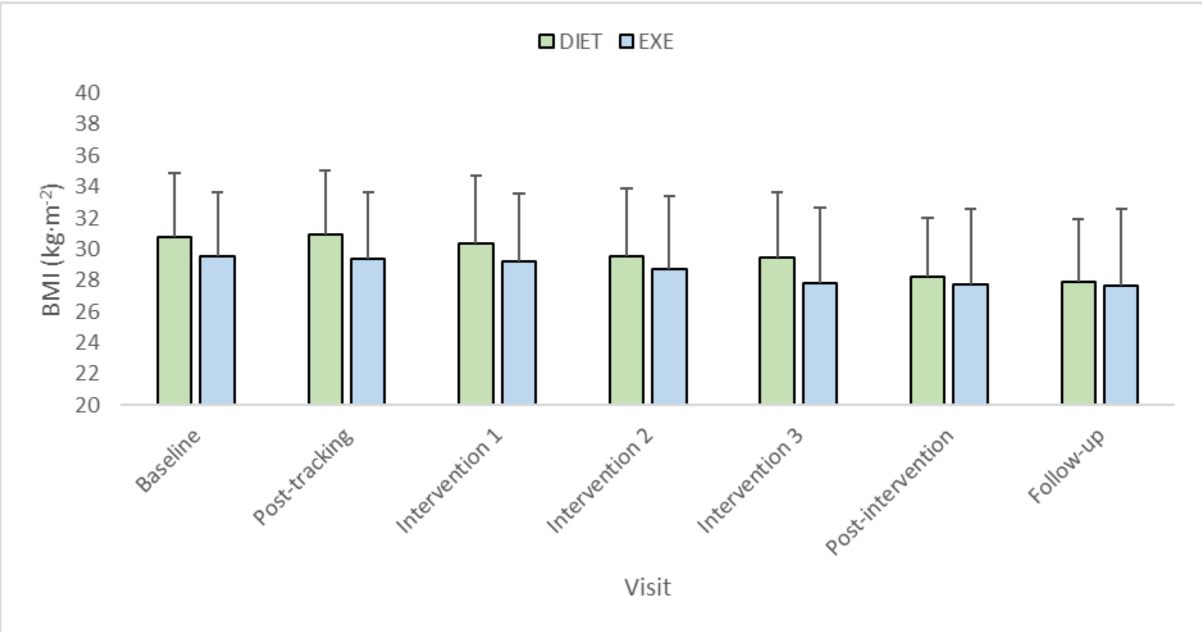

Figure 5.4 Mean (1SD) body mass index in the diet and exercise groups at each study visit.

Table 5.3 Significant post-hoc results for body mass index in the diet group.

Pair	Mean ± SD (kg/m^2)	Mean ± SD (kg/m^2)	Bias-corrected & accelerated 95% confidence interval	T statistic	Degrees of freedom	*p*	*d*	
Visit 1-3	30.79 ± 4.07	30.35 ± 4.34	.124-.746	2.966	16	.009	0.11	Trivial
Visit 1-4	30.46 ± 3.97	29.53 ± 4.35	.535-1.33	5.009	15	.000	0.23	Small
Visit 1-5	30.85 ± 3.79	29.46 ± 4.21	.809-1.96	5.148	14	.000	0.37	Small
Visit 1-6	30.12 ± 3.49	28.18 ± 3.78	1.28-2.60	6.418	12	.000	0.56	Moderate
Visit 1-7	30.12 ± 3.64	27.91 ± 4.04	1.37-3.05	5.774	11	.000	0.61	Moderate
Visit 2-3	30.89 ± 4.13	30.35 ± 4.34	.224-.846	3.647	16	.002	0.13	Trivial
Visit 2-4	30.58 ± 4.06	29.53 ± 4.35	.611-1.49	5.103	15	.000	0.26	Small
Visit 2-5	31.01 ± 3.80	29.46 ± 4.21	.960-2.15	5.614	14	.000	0.41	Small
Visit 2-6	30.32 ± 3.59	28.18 ± 3.78	1.52-2.76	7.539	12	.000	0.60	Moderate
Visit 2-7	30.33 ± 3.75	27.91 ± 4.04	1.63-3.20	6.791	11	.000	0.65	Moderate
Visit 3-4	30.02 ± 4.25	29.53 ± 4.35	.303-.672	5.633	15	.000	0.12	Trivial
Visit 3-5	30.45 ± 4.02	29.46 ± 4.21	.670-1.30	6.683	14	.000	0.25	Small
Visit 3-6	29.65 ± 3.68	28.18 ± 3.78	.986-1.95	6.618	12	.000	0.40	Small
Visit 3-7	29.59 ± 3.84	27.91 ± 4.04	1.05-2.32	5.816	11	.000	0.44	Small
Visit 4-5	29.93 ± 4.19	29.46 ± 4.21	.222-.725	4.035	14	.001	0.11	Trivial
Visit 4-6	29.05 ± 3.71	28.18 ± 3.78	.468-1.26	4.769	12	.000	0.23	Small
Visit 4-7	28.99 ± 3.87	27.91 ± 4.04	.521-1.65	4.240	11	.001	0.28	Small
Visit 5-6	28.58 ± 3.76	28.18 ± 3.78	.047-.753	2.467	12	.030	0.11	Trivial
Visit 5-7	28.55 ± 3.93	27.91 ± 4.04	.166-1.12	2.968	11	.013	0.16	Trivial

Table 5.4 Significant post-hoc results for body mass index in the exercise group.

			Test statistics			
Pair	**Median (IQR)**	**Median (IQR)**	***Z***	***p***	***r***	
Visit 1-5	28.10 (2.98)	26.50 (3.85)	-2.521	.012	-0.89	Large
Visit 1-6	28.10 (2.98)	26.60 (3.68)	-2.521	.012	-0.89	Large
Visit 1-7	28.10 (2.98	26.75 (4.10)	-2.521	.012	-0.89	Large
Visit 2-5	27.70 (3.20)	26.50 (3.85)	-2.527	.012	-0.89	Large
Visit 2-6	27.70 (3.20)	26.60 (3.68)	-2.524	.012	-0.89	Large
Visit 2-7	27.70 (3.20)	26.75 (4.10)	-2.524	.012	-0.89	Large
Visit 3-5	27.35 (3.40)	26.50 (3.85)	-2.533	.011	-0.90	Large
Visit 3-6	27.35 (3.40)	26.60 (3.68)	-2.527	.012	-0.89	Large
Visit 3-7	27.35 (3.40)	26.75 (4.10)	-2.527	.01	-0.89	Large
Visit 4-5	27.15 (3.83)	26.50 (3.85)	-2.371	.018	-0.84	Large
Visit 4-6	27.15 (3.83)	26.60 (3.68)	-2.375	.018	-0.84	Large
Visit 4-7	27.15 (3.83)	26.75 (4.10)	-2.366	.018	-0.84	Large

5.3.4.1.2 Weight

Mixed: There was a significant difference in weight over time (main effect of time; F (6,108) = 40.688; p = 0.000) with the data from both groups combined, but no significant difference in weight between the diet and exercise groups (main effect of group; F (1,18) = 0.010; p = 0.923) irrespective of the measurement time. The pattern of change in weight was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,108) = 2.782; p = 0.084).

Within: In the diet group, weight decreased from 81.59 ± 10.23kg at baseline to 73.67 ± 9.34kg at post-intervention and 73.07 ± 9.85kg at follow-up. In the exercise group, weight decreased from 79.87 ± 12.94kg at baseline to 75.22 ± 14.77kg at post-intervention and 74.88 ± 14.83kg at follow-up. There was a significant effect of time on weight in the diet (F (6,66) = 33.307; p = 0.000) and exercise (χ^2 (6) = 36.857; p = 0.000) group. Figure 5.5 shows the mean (SD) body mass data for both groups at each study visit. Due to the numerous significant [post-hoc] difference between visits for both groups this information is not denoted on Figure 5.5, instead it is presented in Table 5.5 and 5.6.

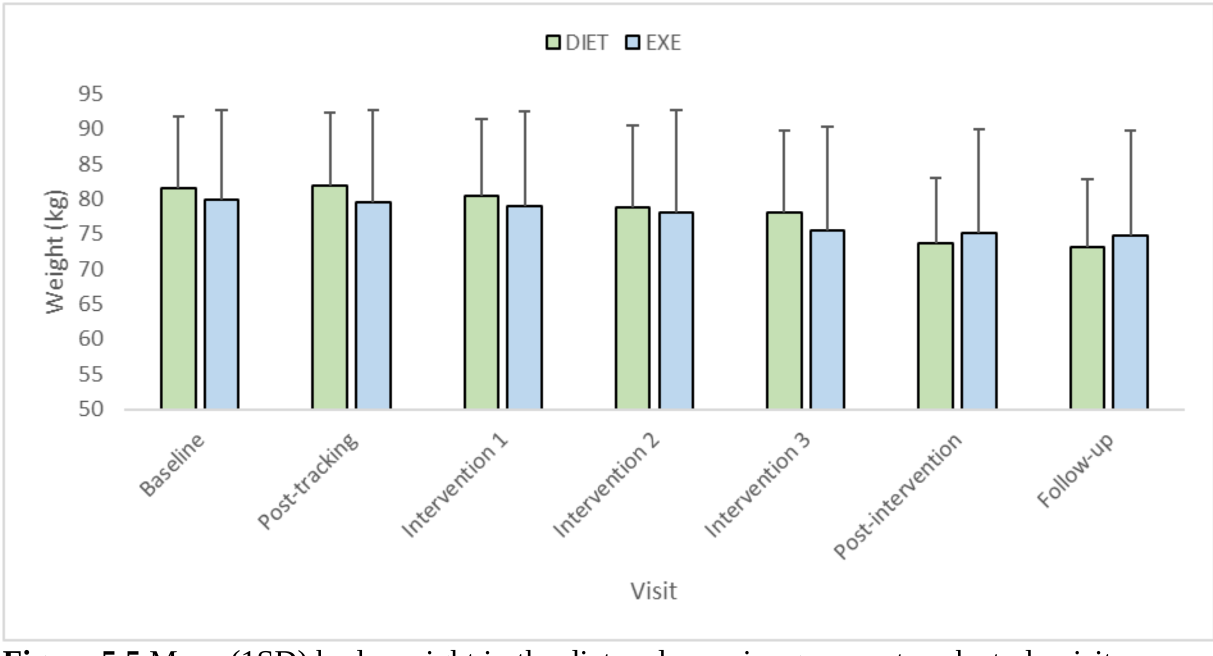

Figure 5.5 Mean (1SD) body weight in the diet and exercise groups at each study visit.

Table 5.5 Significant post-hoc body weight results in the diet group.

Pair	Mean ± SD (kg)	Mean ± SD (kg)	Bias-corrected & accelerated 95% confidence interval	T statistic	Degrees of freedom	*p*	*d*	
Visit 1-3	81.59 ± 10.23	80.52 ± 10.84	.247-1.90	2.966	16	.014	0.10	Trivial
Visit 1-4	81.32 ± 10.50	78.87 ± 11.65	1.28-3.63	5.009	15	.000	0.23	Small
Visit 1-5	81.52 ± 10.83	78.00 ± 11.86	2.04-5.00	5.148	14	.000	0.33	Small
Visit 1-6	78.69 ± 8.48	73.67 ± 9.34	3.29-6.76	6.418	12	.000	0.59	Moderate
Visit 1-7	78.90 ± 8.82	73.07 ± 9.85	3.66-8.00	5.774	11	.000	0.66	Moderate
Visit 2-3	81.95 ± 10.48	80.52 ± 10.84	.685-2.172	3.647	16	.001	0.14	Trivial
Visit 2-4	81.72 ± 10.78	78.87 ± 11.65	1.65-4.06	5.103	15	.000	0.26	Small
Visit 2-5	82.07 ± 11.07	78.00 ± 11.86	2.60-5.55	5.614	14	.000	0.37	Small
Visit 2-6	79.30 ± 8.91	73.67 ± 9.34	3.97-7.30	7.539	12	.000	0.44	Small
Visit 2-7	79.52 ± 9.27	73.07 ± 9.85	4.40-8.50	6.791	11	.000	0.70	Moderate
Visit 3-4	80.23 ± 11.13	78.87 ± 11.65	.845-1.88	5.633	15	.000	0.12	Trivial
Visit 3-5	80.59 ± 11.42	78.00 ± 11.86	1.76-3.42	6.683	14	.000	0.23	Small
Visit 3-6	77.54 ± 8.74	73.67 ± 9.34	2.64-5.12	6.618	12	.000	0.44	Small
Visit 3-7	77.60 ± 9.13	73.07 ± 9.85	2.92-6.15	5.816	11	.000	0.50	Moderate
Visit 4-5	79.17 ± 12.00	78.00 ± 11.86	.584-1.74	4.035	14	.001	0.10	Trivial
Visit 4-6	75.86 ± 8.89	73.67 ± 9.34	1.19-3.20	4.769	12	.000	0.25	Small
Visit 4-7	75.93 ± 9.28	73.07 ± 9.85	1.44-4.29	4.240	11	.001	0.31	Small
Visit 5-6	74.77 ± 8.90	73.67 ± 9.34	.276-1.94	2.467	12	.013	0.12	Trivial
Visit 5-7	74.90 ± 9.28	73.07 ± 9.85	.719-2.95	2.968	11	.004	0.20	Small

Table 5.6 Significant post-hoc body weight results in the exercise group.

			Test statistics			
Pair	Median (IQR)	Median (IQR)	*Z*	*p*	*r*	
Visit 1-5	73.77 (13.99)	70.56 (11.76)	-2.521	.012	-0.89	Large
Visit 1-6	73.77 (13.99)	70.65 (10.16)	-2.521	.012	-0.89	Large
Visit 1-7	73.77 (13.99)	70.92 (9.09)	-2.521	.012	-0.89	Large
Visit 2-5	73.10 (14.23)	70.56 (11.76)	-2.527	.012	-0.89	Large
Visit 2-6	73.10 (14.23)	70.65 (10.16)	-2.524	.012	-0.89	Large
Visit 2-7	73.10 (14.23)	70.92 (9.09)	-2.524	.012	-0.89	Large
Visit 3-5	72.01 (12.67)	70.56 (11.76)	-2.533	.011	-0.90	Large
Visit 3-6	72.01 (12.67)	70.65 (10.16)	-2.527	.012	-0.89	Large
Visit 3-7	72.01 (12.67)	70.92 (9.09)	-2.527	.01	-0.89	Large
Visit 4-5	72.37 (11.72)	70.56 (11.76)	-2.371	.018	-0.84	Large
Visit 4-6	72.37 (11.72)	70.65 (10.16)	-2.375	.018	-0.84	Large
Visit 4-7	72.37 (11.72)	70.92 (9.09)	-2.366	.018	-0.84	Large

5.3.4.2 Secondary Outcomes

5.3.4.2.1 Physical Measures

5.3.4.2.1.1 DXA Results

5.3.4.2.1.1.1 Fat Mass

Mixed: In the combined diet and exercise groups, FM decreased from 35.34 ± 8.38kg at baseline to 32.56 ± 10.33kg at post-intervention and 32.51 ± 13.37kg at follow-up. There was no significant difference in FM over time (main effect of time; $F(3,9) = 3.203$; $p = 0.161$) with the data from both groups combined and no significant difference in FM between the diet and exercise groups (main effect of group; $F(1,3) = 1.482$; $p = 0.311$) irrespective of measurement time. The pattern of change in FM was similar [no significant differences] between the diet and exercise groups (group x time interaction; $F(3,9) = 5.168$; $p = 0.096$).

5.3.4.2.1.1.2 Fat Mass Percentage

Mixed: In the combined diet and exercise groups, FM% decreased from 43.24 ± 5.20% at baseline to 41.88 ± 5.79% at post-intervention and 42.19% ± 7.44% at follow-up. There was no significant difference in fat mass percentage (FM%) over time (main effect of time; $F(3,9) = .188$; $p = 0.902$) with the data from both groups combined and no significant difference in FM% between the diet and exercise groups (main effect of group; $F(1,3) = 5.342$; $p = 0.104$) irrespective of measurement time. The pattern of change in FM% was similar [no significant differences] between the diet and exercise groups (group x time interaction; $F(3,9) = 3.294$; $p = 0.072$).

5.3.4.2.1.1.3 Fat-Free Mass

Mixed: In the combined diet and exercise groups, FFM decreased from 45.53 ± 4.52kg at baseline to 44.58 ± 4.45kg at post-intervention and 42.94 ± 5.17kg at follow-up. There was a significant difference in FFM over time (main effect of time; $F(3,9) = 15.818$; $p = 0.001$) with the data from both groups combined, but no significant difference in FFM between the diet and exercise groups (main effect of group; $F(1,3) = 0.023$; $p = 0.890$) irrespective of measurement time. The pattern of change in FFM was significantly different between the diet and exercise groups (group x time interaction; $F(3,9) = 6.062$; $p = 0.015$).

5.3.4.2.1.1.4 Fat-Free Mass Percentage

Mixed: In the combined diet and exercise groups, FFM% increased from 56.71 ± 5.49% at baseline to 59.21 ± 6.17% at post-intervention and 58.86 ± 8.07% at follow-up. There was no significant difference in fat-free mass percentage (FFM%) over time (main effect of time; F (3,12) = 4.543; p = 0.095) with the data from both groups combined and no significant difference in FFM% between the diet and exercise groups (main effect of group; F (1,4) = 5.320; p = 0.082) irrespective of measurement time. The pattern of change in FFM% was similar [no significant difference] between the diet and exercise groups (group x time interaction; F (3,12) = 3.827; p = 0.118).

5.3.4.2.1.1.5 Fat Mass Index

Mixed: In the combined diet and exercise groups, FMI decreased from 13.27 ± 3.25kg/m^2 at baseline to 12.06 ± 3.53kg/m^2 post-intervention and 12.20 ± 4.62kg/m^2 at follow-up. There was a significant difference in FMI over time (main effect of time; F (3,12) = 5.270; p = 0.015) with the data from both groups combined, but no significant difference in FMI between the diet and exercise groups (main effect of group; F (1,4) = 2.299; p = 0.204) irrespective of measurement time. The pattern of change in FMI was significantly different between the diet and exercise groups (group x time interaction; F (3,12) = 7.650; p = 0.004).

5.3.4.2.1.1.6 Android/Gynoid Ratio

Mixed: In the combined diet and exercise groups, A/G ratio decreased from 0.45 ± 0.10 at baseline to 0.44 ± 0.10 post-intervention and 0.43 ± 0.13 at follow-up. There was no significant difference in A/G ratio over time (main effect of time; F (3,12) =1.031; p = 0.389) with the data from both groups combined and no significant difference in AG ratio between the diet and exercise groups (main effect of group; F (1,4) = 1.079; p = 0.358) irrespective of measurement time. The pattern of change in A/G ratio was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (3,12) = 1.954; p = 0.217).

5.3.4.2.1.1.7 Trunk/Leg Ratio

Mixed: In the combined diet and exercise groups, trunk/leg ratio decreased from 1.05 ± 0.13 at baseline to 1.03 ± 0.09 post-intervention and 1.02 ± 0.12 at follow-up. There was no significant difference in trunk/leg ratio over time (main effect of time; F (3,12) = .569; p = 0.646) with the data from both groups combined and no significant difference in trunk/leg ratio between the diet and exercise groups (main effect of group; F (1,4) = 3.032; p = 0.157) irrespective of measurement time. The pattern of change in trunk/leg ratio was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (3,12) = 1.332; p = 0.310).

5.3.4.2.1.1.8 Trunk/Limb Ratio

Mixed: In the combined diet and exercise groups, trunk/limb ratio decreased from 1.10 ± 0.20 at baseline to 1.09 ± 0.19 post-intervention and 1.06 ± 0.21 at follow-up. There was no significant difference in trunk/limb ratio over time (main effect of time; F (3,12) = .513; p = 0.681) with the data from both groups combined and no significant difference in trunk/limb ratio between the diet and exercise groups (main effect of group; F (1,4) = 0.669; p = 0.459) irrespective of measurement time. The pattern of change in trunk/limb ratio was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (3,12) = 2.307; p = 0.129).

5.3.4.2.1.2 Girths

During COVID-19 associated lockdowns, participants were initially asked to provide girth measurements with the help of a partner. It was decided, however, not to include these data (*i.e.*, the lockdown data generated by the participants) in the final analysis due to the unreliable nature of these data.

5.3.4.2.1.2.1 Hip

Mixed: There was a significant difference in hip circumference over time (main effect of time; F (6,24) = 10.450; p = 0.003) with the data from both groups combined, but no significant difference in hip circumference between the diet and exercise groups (main effect of group; F (1,4) = 0.968; p = 0.381) irrespective of measurement time. The pattern of change in hip circumference was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,24) = 2.687; p = 0.109).

Within: In the diet group, hip circumference decreased from 114.38 ± 9.99cm at baseline to 104.92 ± 4.41cm at post-intervention and 105.00 ± 6.14cm at follow-up. In the exercise group, hip circumference increased from 112.10 ± 9.77cm at baseline to 112.63 ± 15.07cm at post-intervention and decreased to 111.67 ± 19.66cm at follow-up. There was a significant effect of time on hip circumference in the diet group ($\chi2$ (6) = 21.408; p = 0.002), but not in the exercise group (F (6,6) = 1.821; p = 0.406). Post-hoc analysis showed significant reductions in hip circumferences in the diet group between the following visits; visit 1 & 6 (*Z* = -2.207; p = .027;

r = -0.90; large); visit 2 & 4 (*Z* = -2.940; p = .003; *r* = -0.85; large); visit 2 & 5 (*Z* = -2.673; p = .008; *r* = -0.85; large); visit 2 & 6 (*Z* = -2.201; p = .028; *r* = -0.90; large); visit 3 & 4 (*Z* = -2.176; p = .030; *r* = -0.63; moderate); visit 3 & 5 (*Z* = -2.524; p = .012; *r* = -0.80; large); visit 3 & 6 (*Z* = -2.214; p = .027; *r* = -0.90; large); and visit 4 & 6 (*Z* = -2.032; p = .042; *r* = -0.83; large).

5.3.4.2.1.2.2 Waist

Mixed: There was a significant difference in waist circumference over time (main effect of time; F (6,24) = 10.450; p = 0.005) with the data from both groups combined, but no significant difference in waist circumference between the diet and exercise groups (main effect of group; F (1,4) = 1.267; p = 0.323) irrespective of measurement time. The pattern of change in waist circumference was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,24) = 1.540; p = 0.269).

Within: In the diet group, waist circumference decreased from 91.00 ± 6.51cm at baseline to 81.83 ± 5.67cm at post-intervention and 81.00 ± 7.71cm at follow-up. In the exercise group, waist circumference decreased from 91.05 ± 11.44cm at baseline to 90.13 ± 13.11cm at post-intervention and 89.17 ± 16.75cm at follow-up. There was a significant effect of time on waist circumference in the diet group (F (6,18) = 12.327; p = 0.013), but not in the exercise group (χ^2 (6) = 9.847; p = 0.131). Table 5.7 shows the significant [post-hoc] differences in waist girth in the diet group.

Table 5.7 Significant post-hoc waist girth results in the diet group.

Pair	Mean ± SD (cm)	Mean ± SD (cm)	Bias-corrected & accelerated 95% confidence interval	T statistic	Degrees of freedom	*p*	*d*	
Visit 1-3	91.00 ± 6.51	88.29 ± 6.43	1.38-4.03	4.324	16	.001	0.34	Small
Visit 1-4	89.63 ± 5.72	86.00 ± 6.47	1.50-5.75	3.747	11	.003	0.50	Moderate
Visit 1-5	91.00 ± 5.17	85.90 ± 6.63	2.76-7.44	4.941	9	.001	0.73	Moderate
Visit 1-6	88.67 ± 4.76	81.83 ± 5.57	3.85-9.81	5.893	5	.002	1.11	Large
Visit 1-7	89.25 ± 5.91	81.00 ± 7.71	2.87- 13.63	4.883	3	.016	1.03	Large
Visit 2-3	90.32 ± 6.09	88.29 ± 6.43	1.24-2.82	5.449	16	.000	0.27	Small
Visit 2-4	88.83 ± 5.41	86.00 ± 6.47	1.39-4.28	4.324	11	.001	0.40	Small
Visit 2-5	90.20 ± 4.83	85.90 ± 6.63	2.68-5.92	6.008	9	.000	0.64	Moderate
Visit 2-6	88.25 ± 4.19	81.83 ± 5.57	3.90-8.93	6.559	5	.001	1.12	Large
Visit 2-7	88.88 ± 5.27	81.00 ± 7.71	3.80-11.95	6.148	3	.009	1.04	Large
Visit 3-5	87.70 ± 5.93	85.90 ± 6.63	.679-2.92	3.632	9	.005	0.24	Small
Visit 3-6	85.33 ± 5.17	81.83 ± 5.57	1.54-5.46	4.583	5	.006	0.54	Moderate
Visit 3-7	85.13 ± 6.66	81.00 ± 7.71	.486-7.76	3.608	3	.037	0.48	Small
Visit 4-5	87.20 ± 6.43	85.90 ± 6.63	.358-2.24	3.122	9	.012	0.16	Small
Visit 4-6	84.83 ± 5.37	81.83 ± 5.57	.653-5.35	3.286	5	.022	0.45	Small

5.3.4.2.1.2.3 Waist:Hip Ratio

Mixed: There was no significant difference in waist: hip ratio over time (main effect of time; F (6,24) = 2.518; p = 0.133) with the data from both groups combined and no significant difference in waist: hip ratio between the diet and exercise groups (main effect of group; F (1,4) = 2.012; p = 0.229) irrespective of measurement time. The pattern of change in waist:hip ratio was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,24) = 0.739; p = 0.518).

Within: In the diet group, waist: hip ratio decreased from 0.80 ± 0.05 at baseline to 0.78 ± 0.03 at post-intervention and 0.77 ± 0.03 at follow-up. In the exercise group, waist: hip ratio decreased from 0.81 ± 0.04 at baseline to 0.80 ± 0.01 at post-intervention and 0.80 ± 0.02 at follow-up. There was no significant effect of time on waist: hip ratio in the diet group (F (6,18) = 2.062; p = 0.206) or exercise group (F (6,6) = 0.866; p = 0.523).

5.3.4.2.1.2.4 Thigh

Mixed: There was a significant difference in thigh circumference over time (main effect of time; F (6,24) = 6.711; p = 0.000) with the data from both groups combined, but no significant difference in thigh circumference between the diet and exercise groups (main effect of group; F (1,4) = 0.129; p = 0.738) irrespective of measurement time. The pattern of change in thigh circumference was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,24) = 0.936; p = 0.488).

Within: In the diet group, thigh circumference decreased from 66.66 ± 17.91cm at baseline to 63.50 ± 4.38cm at post-intervention and 63.63 ± 5.94cm at follow-up. In the exercise group, thigh circumference increased from 62.85 ± 5.35cm at baseline to 65.13 ± 5.06cm at post-intervention and decreased to 62.50 ± 8.19cm at follow-up. There was no significant effect of time on thigh circumference in the diet group (F (6,18) = 2.398; p = 0.194) or exercise group (F (6,6) = 28.441; p = 0.118).

5.3.4.2.1.2.5 Calf

Mixed: There was no significant difference in calf circumference over time (main effect of time; F (6,24) = 1.011; p = 0.441) with the data from both groups combined and no significant difference in calf circumference between the diet and exercise groups (main effect of group; F (1,4) = 0.121; p = 0.746) irrespective of measurement time. The pattern of change in calf circumference was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,24) = 1.837; p = 0.134).

Within: In the diet group, calf circumference decreased from 41.03 ± 2.35cm at baseline to 38.67 ± 2.50cm at post-intervention and 39.00 ± 3.58cm at follow-up. In the exercise group, calf circumference increased from 40.45 ± 1.66cm at baseline to 41.25 ± 2.90cm at post-intervention and decreased to 40.00 ± 3.61cm at follow-up. There was no significant effect of time on calf circumference in the diet group (F (6,18) = 2.389; p = 0.174) or exercise group (F (6,6) = 0.979; p = 0.503).

5.3.4.2.1.2.6 Bust

Mixed: There was a significant difference in bust circumference over time (main effect of time; F (6,24) = 4.187; p = 0.005) with the data from both groups combined, but no significant difference in bust circumference between the diet and exercise groups (main effect of group; F (1,4) = 2.776; p = 0.171) irrespective of measurement time. The pattern of change in bust circumference was different between the diet and exercise groups (group x time interaction; F (6,24) = 5.907; p = 0.001).

Within: In the diet group, bust circumference decreased from 103.76 ± 5.81cm at baseline to 97.00 ± 5.29cm at post-intervention and 95.00 ± 5.32cm at follow-up. In the exercise group, bust circumference increased from 105.35 ± 7.97cm at baseline to 106.88 ± 11.68cm at post-intervention and decreased to 105.17 ± 14.84cm at follow-up. Table 5.8 shows the significant post-hoc findings for bust circumference in the diet group. There was a statistically significant effect of time on bust circumference in the diet group (F (6,18) = 13.130; p = 0.009), but not in the exercise group (F (6,6) = 0.816; p = 0.532).

5.3.4.2.1.2.7 Upper arm

Mixed: There was no significant difference in upper arm circumference over time (main effect of time; F (6,24) = 0.961; p = 0.442) with the data from both groups combined and no significant difference in upper arm circumference between the diet and exercise groups (main effect of group; F (1,4) = 0.551; p = 0.499) irrespective of measurement time. The pattern of change in upper arm circumference was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,24) = 0.547; p = 0.659).

Within: In the diet group, upper arm circumference decreased from 34.03 ± 3.77cm at baseline to 32.75 ± 2.54cm at post-intervention and 33.75 ± 3.57cm at follow-up. In the exercise group, upper arm circumference decreased from 34.70 ± 3.51cm at baseline to 34.38 ± 3.15cm at post-intervention and 34.50 ± 5.07cm at follow-up. There was no significant effect of time on upper arm circumference in the diet group ($\chi2$ (6) = 7.934; p = 0.243) or exercise group (F (1,1) = 0.644; p = 0.569).

Table 5.8 Significant post-hoc bust girth results in the diet group.

Pair	Mean ± SD (cm)	Mean ± SD (cm)	Bias-corrected & accelerated 95% confidence interval	T statistic	Degrees of freedom	*p*	*d*	
Visit 1-6	101.92 ± 3.61	97.00 ± 5.29	2.40-7.43	5.026	5	.004	-0.95	Large
Visit 1-7	101.00 ± 4.24	95.00 ± 5.32	3.95-8.05	9.295	3	.003	-1.06	Large
Visit 2-5	103.55 ± 5.20	101.00 ± 7.25	.639-4.46	3.019	9	.015	-0.35	Small
Visit 2-6	101.67 ± 3.91	87.00 ± 5.29	2.21-7.12	4.889	5	.005	-0.86	Large
Visit 2-7	100.38 ± 3.71	95.00 ± 5.32	.719- 10.03	3.674	3	.035	-1.02	Large
Visit 3-6	100.75 ± 4.44	97.00 ± 5.29	1.46-6.04	4.204	5	.008	-0.65	Moderate
Visit 3-7	99.00 ± 4.42	95.00 ± 5.32	.752-7.25	3.919	3	.030	-0.69	Moderate
Visit 4-6	100.75 ± 5.19	97.00 ± 5.29	2.17-5.33	6.090	5	.002	-0.59	Moderate
Visit 4-7	98.38 ± 4.71	95.00 ± 5.32	1.09-5.66	4.700	3	.018	-0.56	Moderate
Visit 5-6	98.25 ± 5.25	97.00 ± 5.29	.112-2.39	2.825	5	.030	-0.19	Moderate

5.3.4.2.1.3 Bloods

Participant 25 did not provide a blood sample at any visit, other than for analysis of HbA1c at visit 1. TG values at visit 1 were analysed across 15 participants in the diet group due to a linearity error with P23. At visit 2, a linearity error occurred on the Pentra when attempting to analyse P09 samples therefore no results were obtained, and insufficient sample was obtained from P15, therefore only HDL and TG results were obtained.

5.3.4.2.1.3.1 Total Cholesterol

Mixed: In the combined diet and exercise groups, total cholesterol decreased from 4.98 ± 1.02mmol/l at baseline to 4.85 ± 1.55mmol/l at pre-intervention, 4.52 ± 0.72mmol/l at post-intervention and 4.32 ± 0.33mmol/l at follow-up. There was no significant difference in TC over time (main effect of time; $F(3,9) = 0.282$; $p = 0.837$) with the data from both groups combined and no significant difference in TC between the diet and exercise groups (main effect of group; $F(1,3) = 0.101$; $p = 0.772$) irrespective of measurement time. The pattern of change in TC was similar [no significant differences] between the diet and exercise groups (group x time interaction; $F(3,9) = 2.432$; $p = 0.132$).

5.3.4.2.1.3.2 High-density Lipoprotein Cholesterol

Mixed: In the combined diet and exercise groups, HDL decreased from 1.50 ± 0.35mmol/l at baseline to 1.42 ± 0.36mmol/l at pre-intervention and increased to 1.54 ± 0.27mmol/l at post-intervention and 1.54 ± 0.31mmol/l at follow-up. There was no significant difference in HDL over time (main effect of time; F (3,6) = 4.082; p = 0.067) with the data from both groups combined and no significant difference in HDL between the diet and exercise groups (main effect of group; F (1,2) = 3.752; p = 0.192) irrespective of measurement time. The pattern of change in HDL was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (3,6) = 0.624; p = 0.625).

5.3.4.2.1.3.3 Low-density Lipoprotein Cholesterol

Mixed: In the combined diet and exercise groups, LDL increased from 2.88 ± 0.82mmol/l at baseline to 2.97 ± 0.86mmol/l at pre-intervention, 2.97 ± 0.99mmol/l at post-intervention and 3.04 ± 0.49mmol/l at follow-up. There was no significant difference in LDL over time (main effect of time; F (3,6) = 0.827; p = 0.525) with the data from both groups combined and no significant difference in LDL between the diet and exercise groups (main effect of group; F (1,2) = 1.879; p = 0.304) irrespective of measurement time. The pattern of change in LDL was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (3,6) = 0.691; p = 0.590).

5.3.4.2.1.3.4 Triglycerides

Mixed: In the combined diet and exercise groups, TG increased from 1.25 ± 0.87mmol/l at baseline to 1.26 ± 0.87mmol/l at pre-intervention and decreased to 0.80 ± 0.31mmol/l at post-intervention and 0.89 ± 0.48mmol/l at follow-up. There was no significant difference in TG over time (main effect of time; F (3,6) = 3.353; p = 0.198) with the data from both groups combined and no significant difference in TG between the diet and exercise groups (main effect of group; F (1,2) = 0.568; p = 0.530) irrespective of measurement time. The pattern of change in TG was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (3,6) = 1.164; p = 0.395).

5.3.4.2.1.3.5 HbA1c

In the combined diet and exercise groups, HbA1c increased from 5.47 ± 0.27% at baseline to 5.77 ± 0.45% at post-intervention. In the combined groups, the change in HbA1c from visit 1 (baseline) to visit 6 (post-intervention) was not significant (t(8), -2.166; p = .062; BCa 95% CI -.528-.017 *d* =-0.61; moderate).

5.3.4.2.1.3.6 Glucose

Mixed: In the combined diet and exercise groups, glucose decreased from 3.72 ± 0.65mmol/l at baseline to 3.49 ± 0.61mmol/l at pre-intervention and increased to 3.96 ± 0.57mmol/l at post-intervention and 4.04 ± 0.81mmol/l at follow-up. There was no significant difference in glucose over time (main effect of time; F (3,12) = 1.325; p = 0.312) with the data from both groups combined and no significant difference in glucose between the diet and exercise groups (main effect of group; F (1,4) = 0.886; p = 0.400) irrespective of measurement time. The pattern of change in glucose was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (3,12) = 0.460; p = 0.715).

5.3.4.2.1.4 Blood Pressure

5.3.4.2.1.4.1 Systolic Blood Pressure

Mixed: There was no significant difference in systolic BP over time (main effect of time; F (6,96) = 1.374; p = 0.233) with the data from both groups combined and no significant difference in systolic BP between the diet and exercise groups (main effect of group; F (1,16) = 0.012; p = 0.913) irrespective of measurement time. The pattern of change in systolic BP was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,96) = 29.525; p = 0.740).

Within: In the diet group, systolic BP decreased from 120.59 ± 8.71mmHg at baseline to 112.92 ± 10.81mmHg at post-intervention and 117.27 ± 10.30mmHg at follow-up. In the exercise group, systolic BP decreased from 116.10 ± 12.11mmHg at baseline to 113.38 ± 6.19mmHg at post-intervention and increased to 117.13 ± 8.15mmHg at follow-up. There was no significant effect of time on systolic BP in the diet group (F (6,54) = 0.892; p = 0.477) or exercise group ($\chi 2$ (6) = 6.217; p = 0.399).

5.3.4.2.1.4.2 Diastolic Blood Pressure

Mixed: There was no significant difference in diastolic BP over time (main effect of time; F (6,96) = 2.039; p = 0.105) with the data from both groups combined and no significant difference in diastolic BP between the diet and exercise groups (main effect of group; F (1,16) = 0.222; p = 0.644) irrespective of measurement time. The pattern of change in diastolic BP was similar [no significant differences] between the diet and exercise groups (group x time interaction; $F(6,96) = 1.011$; $p = 0.406$).

Within: In the diet group, diastolic BP decreased from 87.29 ± 9.75mmHg at baseline to 82.08 ± 7.55mmHg at post-intervention and 82.09 ± 12.90mmHg at follow-up. In the exercise group, diastolic BP decreased from 87.30 ± 10.14mmHg at baseline to 79.25 ± 10.94mmHg at post-intervention and 82.00 ± 8.93mmHg at follow-up. There was no significant effect of time on diastolic BP in the diet group ($F(6,54) = 1.065$; $p = 0.395$) or exercise group ($F(6,42) = 1.826$; $p = 0.117$).

5.3.4.2.1.5 Resting Heart Rate

Mixed: There was no significant difference in resting HR over time (main effect of time; $F(6,96) = 0.425$; $p = 0.861$) with the data from both groups combined and no significant difference in resting HR between the diet and exercise groups (main effect of group; $F(1,16) = 0.053$; $p = 0.821$) irrespective of measurement time. The pattern of change in resting HR was similar [no significant differences] between the diet and exercise groups (group x time interaction; $F(6,96) = 0.558$; $p = 0.762$).

Within: In the diet group, resting HR increased from 66.53 ± 9.66bpm at baseline to 67.25 ± 9.87bpm at post-intervention and decreased to 65.00 ± 7.56bpm at follow-up. In the exercise group, resting HR decreased from 66.50 ± 6.64bpm at baseline to 64.88 ± 6.88bpm at post-intervention and increased to 67.25 ± 7.21bpm at follow-up. There was no significant effect of time on resting HR in the diet group ($F(6,54) = 0.567$; $p = 0.755$) or exercise group ($\chi^2(6) = 4.083$; $p = 0.665$).

5.3.4.2.2 Behavioural Measures

5.3.4.2.2.1 Fitbit Results

Participant 7 had no data in block 6 and participant 21 had no data in block 4, due to non-wear periods which were as a result of forgetting to put the Fitbit back on after charging.

5.3.4.2.2.1.1 Steps

Mixed: There was a significant difference in daily steps over time (main effect of time; F (5,80) = 7.368; p = 0.000) with the data from both groups combined, but no significant difference in daily steps between the diet and exercise groups (main effect of group; F (1,16) = 0.992; p = 0.334) irrespective of measurement time. The pattern of change in total daily steps was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (5,80) = 1.070; p = 0.373).

Within: In the diet group, daily steps increased from 8579.59 ± 1949.45 in the tracking period to 9939.27 ± 2580.87 in intervention block 4 and 10314.25 ± 2304.34 in the follow-up period. In the exercise group, steps increased from 6691.10 ± 1971.59 in the tracking period to 8823.63 ± 3962.49 in intervention block 4 and 9181.14 ± 3374.27 in the follow-up period. There was a significant effect of time on total daily steps in the diet group (F (5,50) = 4.802; p = 0.01) and exercise group (F (5,30) = 3.286; p = 0.17). Post hoc analysis showed no significant differences in steps between any of the blocks in the diet group. In the exercise group, there were significant increases in total daily steps between the following blocks; block 1 & 2 (t(9), -5.284; p = .001; BCa 95% CI -2275.26 - -1111.34 d =-0.70; moderate); block 1 & 3 (t(9), -4.016; p = .003; BCa 95% CI -2681.13- -749.07 d =-0.62; moderate); block 1 & 4 (t(8), -3.913; p = .004; BCa 95% CI -3295.03- -851.41 d =-0.67; moderate); and block 1 & 6 (t(6), -2.784; p = .032; BCa 95% CI -3551.15- -228.57 d =-0.59; moderate); Figure 5.6.

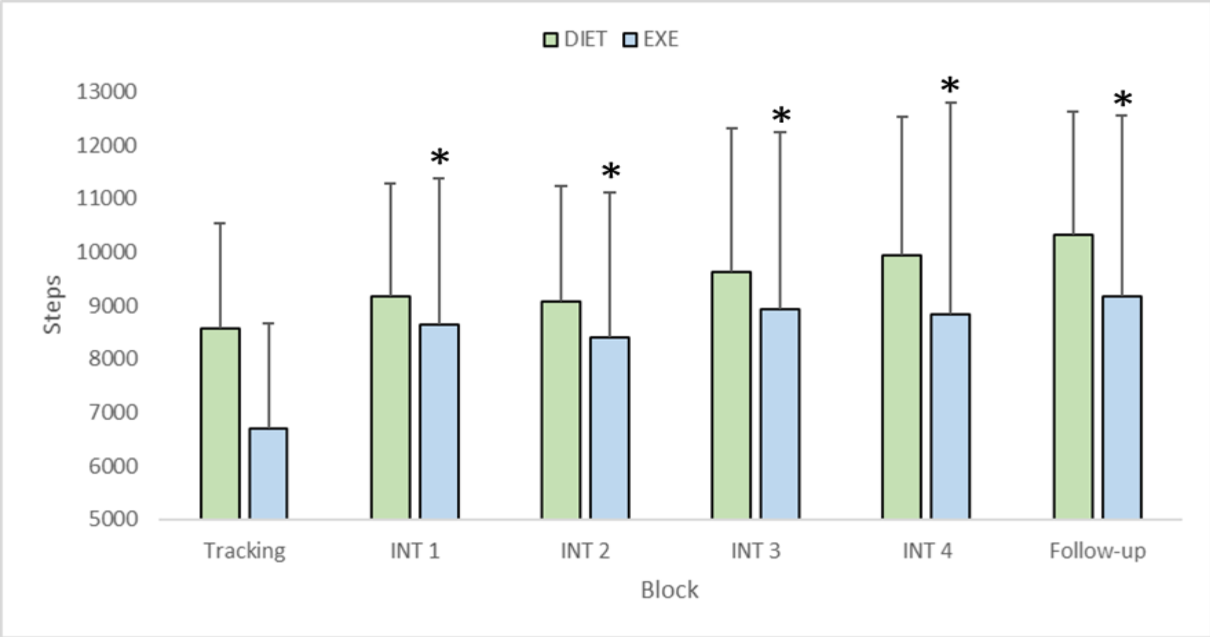

Figure 5.6 Mean (1SD) total daily steps in diet and exercise groups in each block of the study (time between visits). Abbreviations: INT 1-4, intervention blocks 1-4. * indicates significant increase (p<0.05) from tracking.

5.3.4.2.2.1.3 Distance

Mixed: There was a significant difference in daily distance over time (main effect of time; F (5,85) = 7.226; p = 0.000) with the data from both groups combined, but no significant difference in distance between the diet and exercise groups (main effect of group; F (1,17) = 0.457; p = 0.508) irrespective of measurement time. The pattern of change in total daily distance was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (5,85) = 0.880; p = 0.461).

Within: In the diet group, daily distance increased from 5.60 ± 1.41km in the tracking period to 6.74 ± 1.98km in intervention block 4 and 7.08 ± 1.57km in the follow-up period. In the exercise group, daily distance increased from 4.63 ± 1.40km in the tracking period to 6.26 ± 2.96km in intervention block 4 and 6.46 ± 2.44km in the follow-up period. There was a significant effect of time on total daily distance in the diet group (F (5,55) = 4.665; p = 0.01), but not in the exercise group (F (5,30) = 3.209; p = 0.86). Post hoc analysis showed significantly higher total daily distance in the diet group between blocks 1 & 5 (t(14), -2.338; p = .035; BCa 95% CI -1.89 - -.082 *d* =-0.49; small), and blocks 1 & 6 (t(12), -3.163; p = .008; BCa 95% CI -1.91 - -.353 *d* =-0.67; moderate); Figure 5.7.

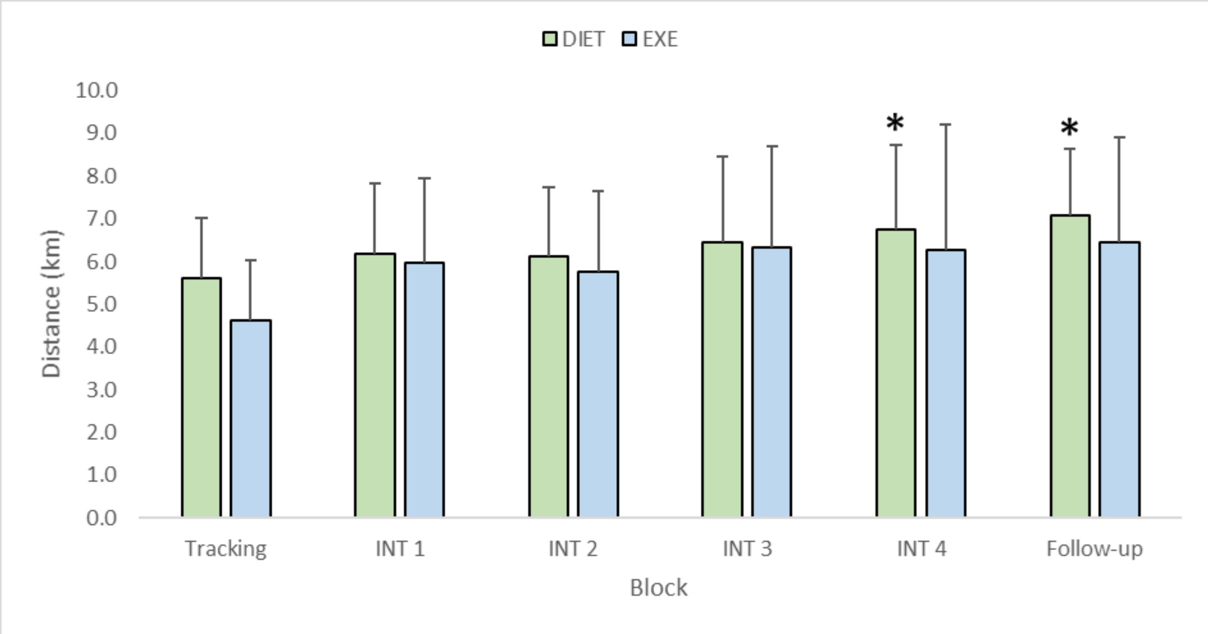

Figure 5.7 Mean (1SD) total daily distance walked in diet and exercise groups in each block of the study (time between visits). Abbreviations: INT 1-4, intervention blocks 1-4. * indicates significant increase (p<0.05) from tracking.

5.3.4.2.2.1.4 Active Minutes

Mixed: There was a significant difference in active minutes over time (main effect of time; F (5,80) = 8.990; p = 0.000) with the data from both groups combined, but no significant difference in active minutes between the diet and exercise groups (main effect of group; F (1,16) = 2.696; p = 0.120) irrespective of measurement time. The pattern of change in active minutes was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (5,80) = 0.830; p = 0.532).

Within: In the diet group, active minutes increased from 31.53 ± 16.70mins in the tracking period to 47.87 ± 24.19mins in intervention block 4 and 49.75 ± 19.62mins in the follow-up period. In the exercise group, active minutes increased from 14.60 ± 13.41mins in the tracking period to 32.63 ± 27.73mins in intervention block 4 and 34.14 ± 23.40 mins in the follow-up period. There was a significant effect of time on total daily active minutes in the diet group (F (5,50) = 6.571; p = 0.000) and in the exercise group (χ2 (5) = 13.833; p = 0.017). Post hoc analysis showed significantly higher total daily active minutes in the diet group between the following blocks; block 1 & 4 (t(13), -2.727; p = .017; BCa 95% CI -16.51 - -1.91 *d* =-0.38; small); block 1 & 5 (t(14), -3.008; p = .009; BCa 95% CI -25.24 - -4.23 *d* =-0.61; moderate); block 1 & 6 (t(11), -2.336; p = .039; BCa 95% CI -25.90 - -.770 *d* =-0.60; moderate); block 2 & 5 (t(14), -2.867; p = .012; BCa 95% CI -17.60 - -2.54 *d* =-0.42; small); block 3 & 4 (t(13), -

2.266; p = .041; BCa 95% CI -8.65 - -.206 *d* =-0.16; small); block 3 & 5 (t(14), -3.225; p = .006; BCa 95% CI -17.54 - -3.53 *d* =-0.40; small); and block 4 & 5 (t(13), -2.591; p = .022; BCa 95% CI -13.49 - -1.22 *d* =-0.25; small). There were significant increases in total daily active minutes in the exercise group between the following blocks; block 1 & 2 (*Z* = -2.805; p = .005; *r* = -0.89; large); block 1 & 3 (*Z* = -2.703; p = .007; *r* = -0.85; large); block 1 & 4 (*Z* = -2.666; p = .008; *r* = -0.89; large); block 1 & 5 (*Z* = -2.524; p = .012; *r* = -0.89; large); and block 1 & 6 (*Z* = -2.028; p = .043; *r* = -0.77; medium); Figure 5.8.

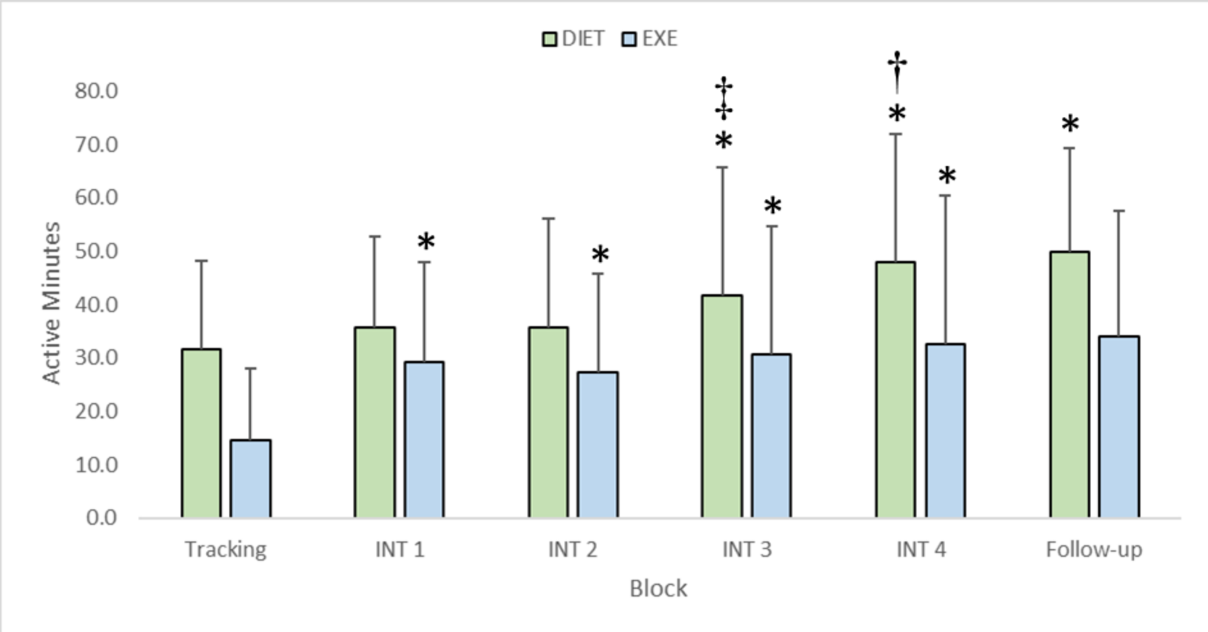

Figure 5.8 Mean (1SD) daily active minutes in diet and exercise groups in each block of the study (time between visits). Abbreviations: INT 1-4, intervention blocks 1-4. * indicates significant increase (p<0.05) from tracking. † indicates significant increase (p>0.05) from blocks INT 1, 2 and 3. ‡ indicates significant increase (p<0.05) from INT 2.

5.3.4.2.2.1.5 Calorie Expenditure

Mixed: There was a significant difference in calorie expenditure over time (main effect of time; F (5,80) = 4.535; p = 0.008) with the data from both groups combined, but no significant difference in calorie expenditure between the diet and exercise groups (main effect of group; F (1,16) = 0.892; p = 0.359) irrespective of measurement time. The pattern of change in total daily calorie expenditure was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (5,80) = 0.929; p = 0.433).

Within: In the diet group, calorie expenditure increased from 2248.76 ± 238.79kcal in the tracking period to 2294.47 ± 239.32kcal in intervention block 4 and 2260.17 ± 245.65kcal in the follow-up period. In the exercise group, calorie expenditure increased from 2124.20 ± 247.41kcal in the tracking period to 2229.25 ± 229.27kcal in intervention block 4 and 2187.86 ± 274.81kcal in the follow-up period. There was no significant effect of time on calorie expenditure in the diet group (F (5,50) = 1.763; p = 0.182) or exercise group (F (5,30) = 2.522; p = 0.051).

5.3.4.2.2.2 Godin-Shephard Leisure-Time Physical Activity Questionnaire

5.3.4.2.2.2.1 Leisure-time Physical Activity Score

Mixed: There was a significant difference in leisure-time physical activity (LTPA) scores over time (main effect of time; F (6,108) = 9.535; p = 0.000) with the data from both groups combined, but no significant difference in LTPA scores between the diet and exercise groups (main effect of group; F (1,18) = 0.121; p = 0.732) irrespective of measurement time. The pattern of change in LTPA scores was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,108) = 1.067; p = 0.387).

Within: In the diet group, LTPA scores increased from 36.53 ± 24.77 at baseline to 54.75 ± 23.34 at post-intervention and 53.25 ± 19.89 at follow-up. In the exercise group, LTPA scores increased from 28.10 ± 18.46 at baseline to 62.75 ± 25.19 at post-intervention and 53.75 ± 23.33 at follow-up. There was a significant effect of time on LTPA scores in the diet group (F (6,66) = 3.472; p = 0.005) and exercise group (χ^2 (6) = 25.032; p = 0.000). Post hoc analysis showed significantly higher LTPA scores in the diet group between the following visits; visit 1 & 6 (t(12), -2.263; p = .043; BCa 95% CI -35.03 - -.660 *d* =-0.60; moderate); visit 2 & 6 (t(12), -2.732; p = .018; BCa 95% CI -34.01 - -3.83 *d* =-0.72; moderate); and visit 3 & 6 (t(12), -3.105; p = .009; BCa 95% CI -26.97 - -4.73 *d* =-0.61; moderate). In the exercise group, significant increases in LTPA scores were shown between visit 1 and visits 3, 4, 5, 6 and 7 and between visits 2 and visits 3, 4, 6 and 7 (Table 5.9). There were also increases in LTPA scores between visit 4 and 6 and 5 and 6.

Table 5.9 Significant post-hoc leisure-time physical activity scores from the Godin-Shephard Questionnaire in the exercise group.

			Test statistics			
Pair	**Median (IQR)**	**Median (IQR)**	***Z***	***p***	***r***	
Visit 1-3	31.00 (24.75)	48.00 (32.75)	-2.143	.032	-0.68	Medium
Visit 1-4	31.00 (27.00)	48.50 (32.00)	-2.192	.028	-0.73	Medium
Visit 1-5	23.00 (25.50)	56.00 (23.50)	-2.197	.028	-0.78	Medium
Visit 1-6	31.00 (24.75)	73.00 (17.25)	-2.521	.012	-0.89	Large
Visit 1-7	31.00 (24.75)	65.00 (30.25)	-2.173	.030	-0.77	Medium
Visit 2-3	24.00 (24.50)	48.00 (32.75)	-2.803	.005	-0.89	Large
Visit 2-4	20.00 (27.00)	48.50 (32.00)	-2.668	.008	-0.89	Large
Visit 2-6	25.50 (28.00)	56.00 (23.50)	-2.366	.018	-0.84	Large
Visit 2-7	25.50 (28.00)	65.00 (30.25)	-2.100	.036	-0.77	Medium
Visit 4-6	48.50 (25.25)	73.00 (17.25)	-2.243	.025	-0.79	Medium
Visit 5-6	56.00 (23.50)	73.00 (17.25)	-2.117	.043	-0.75	Medium

5.3.4.2.2.3 Food Recalls

A total of 12 out of 20 study finishers completed all requested food recalls. In the tracking period two participants failed to complete one of the requested food recalls. Twenty-three of 27 participants completed a food recall in block 2 whilst completion rate in block 3 was 24/27. After considering dropouts, in blocks 4 and 5 the completion rate was 21/25 and 21/23, respectively. Completion rate in the final block was 18 out of a possible 21 participants enrolled in the study.

5.3.4.2.2.3.1 Calories

Mixed: There was no significant difference in calorie intake over time (main effect of time; F (5,50) = 2.221; p = 0.067) with the data from both groups combined and no significant difference in calorie intake between the diet and exercise groups (main effect of group; F (1,10) = 0.409; p = 0.537) irrespective of measurement time. The pattern of change in calorie intake was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (5,50) = 0.566; p = 0.725).

Within: In the diet group, daily calorie intake decreased from 2337.07 ± 655.34kcal in the tracking period to 1601.48 ± 794.40kcal in intervention block 4 and 1359.44 ± 1056.37kcal in the follow-up period. In the exercise group, daily calorie intake decreased from 2202.11 ± 712.92kcal in the tracking period to 1711.04 ± 725.54kcal in intervention block 4 and 1758.83 ± 193.85kcal in the follow-up period. There was a significant effect of time on total calorie intake in the diet group (χ^2 (5) = 16.810; p = 0.005), but not in the exercise group (χ^2 (5) = 6.429; p = 0.267). The significant post-hoc findings for the diet group were: Block 1 vs 2: Z = -2.726 p = .006 r = -0.70: medium; Block 1 vs 3: Z = -3.351 p = .001 r = -0.87: large; Block 1 vs 4: Z = -3.180 p = .001 r = -0.88: large; Block 1 vs 5: Z = -2.982 p = .003 r = -0.80: large; and Block 1 vs 6: Z = -1.988 p = .047 r = -0.63: medium; Figure 5.9.

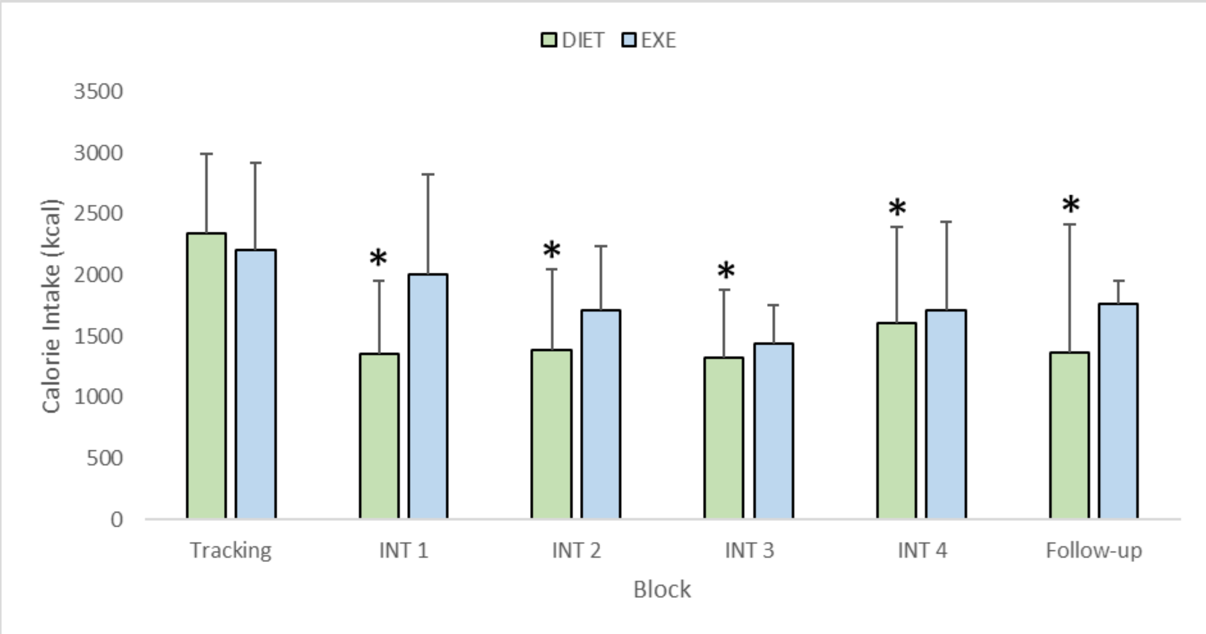

Figure 5.9 Mean (1SD) calorie intake in diet and exercise groups. Abbreviations: INT 1-4, intervention blocks 1-4. * indicates significant decrease ($p<0.05$) from tracking.

5.3.4.2.2.3.2 Fat

Mixed: There was no significant difference in fat intake over time (main effect of time; $F(5,50) = 2.568$; $p = 0.086$) with the data from both groups combined and no significant difference in fat intake between the diet and exercise groups (main effect of group; $F(1,10) = 0.118$; $p = 0.738$) irrespective of measurement time. The pattern of change in fat intake was similar [no significant differences] between the diet and exercise groups (group x time interaction; $F(5,50) = 0.214$; $p = 0.854$).

Within: In the diet group, daily fat intake decreased from 101.78 ± 32.31g in the tracking period to 62.12 ± 55.78g in intervention block 4 and 55.88 ± 67.13g in the follow-up period. In the exercise group, daily fat intake decreased from 91.43 ± 33.83g in the tracking period to 81.10 ± 68.06g in intervention block 4 and 64.46 ± 26.00g in the follow-up period. There was a significant effect of time on total fat intake in the diet group ($\chi^2(5) = 16.365$; $p = 0.006$), but not in the exercise group ($\chi^2(5) = 6.810$; $p = 0.235$). The significant post-hoc findings for the diet group were: Block 1 vs 2: Z = -2.669 p = .008 r = -0.69: medium; Block 1 vs 3: Z = -3.408

p = .001 r = -0.88: large; Block 1 vs 4: Z = -3.180 p = .001 r = -0.88: large; and Block 1 vs 5: Z = -2.354 p = .019 r = -0.63: medium; Figure 5.10.

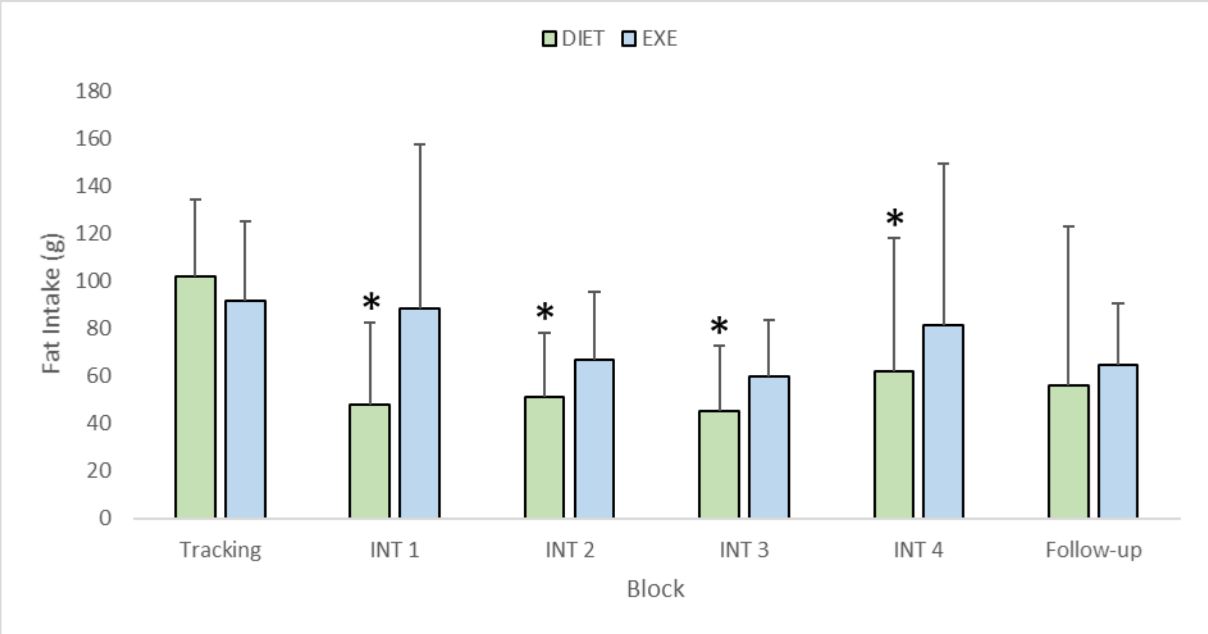

Figure 5.10 Mean (1SD) fat intake in diet and exercise groups. Abbreviations: INT 1-4, intervention blocks 1-4. * indicates significant decrease (p<0.05) from tracking.

5.3.4.2.2.3.4 Saturated Fat

Mixed: There was a significant difference in saturated fat intake over time (main effect of time; F (5,50) = 2.830; p = 0.025) with the data from both groups combined, but no significant difference in saturated fat intake between the diet and exercise groups (main effect of group; F (1,10) = 0.006; p = 0.938) irrespective of measurement time. The pattern of change in saturated fat intake was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (5,50) = 0.788; p = 0.564).

Within: In the diet group, daily saturated fat intake decreased from 37.62 ± 9.43g in the tracking period to 21.48 ± 13.77g in intervention block 4 and 20.24 ± 20.52g in the follow-up period. In the exercise group, daily saturated fat intake decreased from 35.01 ± 12.74g in the tracking period to 34.90 ± 31.68g in intervention block 4 and 20.22 ± 9.73g in the follow-up period. There was a significant effect of time on total saturated fat intake in the diet group (χ2 (5) = 19.476; p = 0.002), but not in the exercise group (χ2 (5) = 9.286; p = 0.098). In the diet group, post hoc analysis showed a significant reduction in saturated fat intake between the following blocks; block 1 & 2 (*Z* = -2.613; p = .009; *r* = -0.67; medium); block 1 & 3 (*Z* = -3.294; p = .001; *r* = -0.85; large); and block 1 & 4 (*Z* = -3.180; p = .001; *r* = -0.88; large); block

1 & 5 (*Z* = -2.731; p = .006; *r* = -0.73; medium). There was a significant increase in saturated fat intake between blocks 3 and 5 (*Z* = -2.132; p = .033; *r* = -0.59; medium), and blocks 4 and 5 (*Z* = -2.132; p = .033; *r* = -0.59; medium), respectively; Figure 5.11.

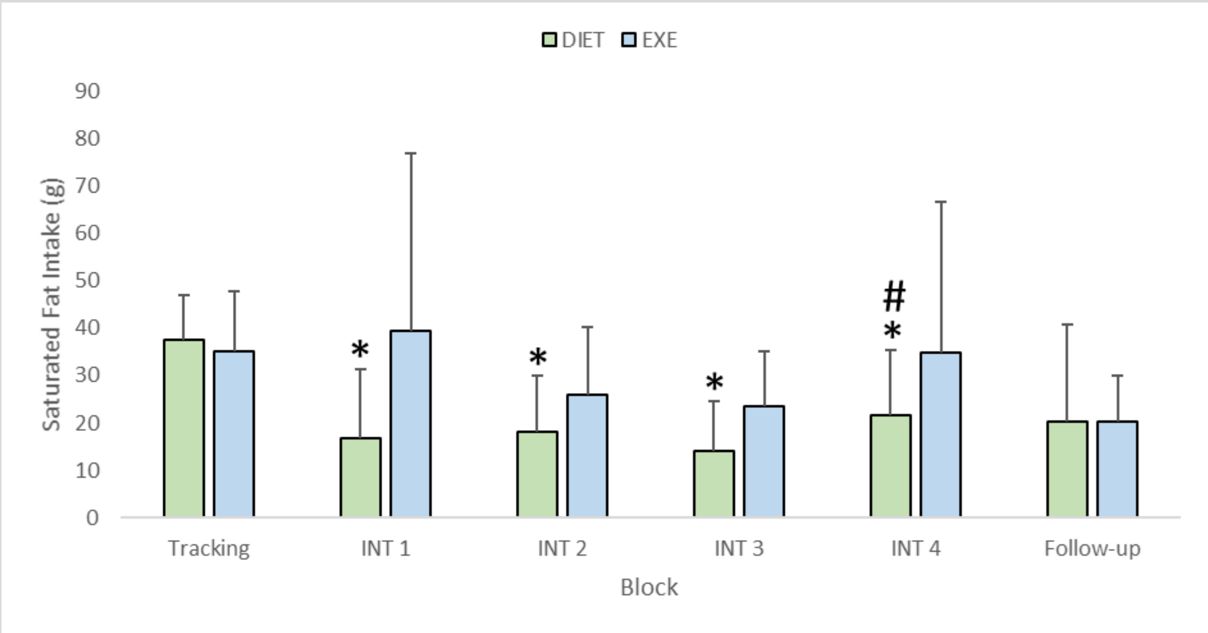

Figure 5.11 Mean (1SD) saturated fat intake in diet and exercise groups. Abbreviations*:* INT 1-4, intervention blocks 1-4. * indicates significant decrease ($p<0.05$) from tracking. # indicates significant increase ($p<0.05$) from INT 2 and 3.

5.3.4.2.2.3.5 Carbohydrates

Mixed: There was no significant difference in carbohydrate intake over time (main effect of time; F (5,50) = 1.642; p = 0.166) with the data from both groups combined and no significant difference in carbohydrate intake between the diet and exercise groups (main effect of group; F (1,10) = 0.744; p = 0.409) irrespective of measurement time. The pattern of change in carbohydrate intake was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (5,50) = 0.825; p = 0.538).

Within: In the diet group, daily carbohydrate intake decreased from 273.68 ± 77.95g in the tracking period to 206.92 ± 97.05g in intervention block 4 and 166.66 ± 123.36g in the follow-up period. In the exercise group, daily carbohydrate intake decreased from 280.62 ± 88.33g in the tracking period to 176.82 ± 29.99g in intervention block 4 and 193.53 ± 76.47g in the follow-up period. There was a significant effect of time on total carbohydrate intake in the diet group ($\chi2$ (5) = 12.111; p = 0.033), but not in the exercise group ($\chi2$ (5) = 5.857; p = 0.320).

The significant post-hoc findings for the diet group were: Block 1 vs 2: Z = -2.669 p = .008 r = -0.69: medium; Block 1 vs 3: Z = -2.726 p = .006 r = -0.70: medium; Block 1 vs 4: Z = -3.110 p = .002 r = -0.86: medium; Block 1 vs 5: Z = -2.605 p = .009 r = -0.69: medium; Block 1 vs 6: Z = -2.090 p = .037 r = -0.66: medium; and Block 5 vs 6: Z = -1.988 p = .047 r = -0.63: medium; Figure 5.12.

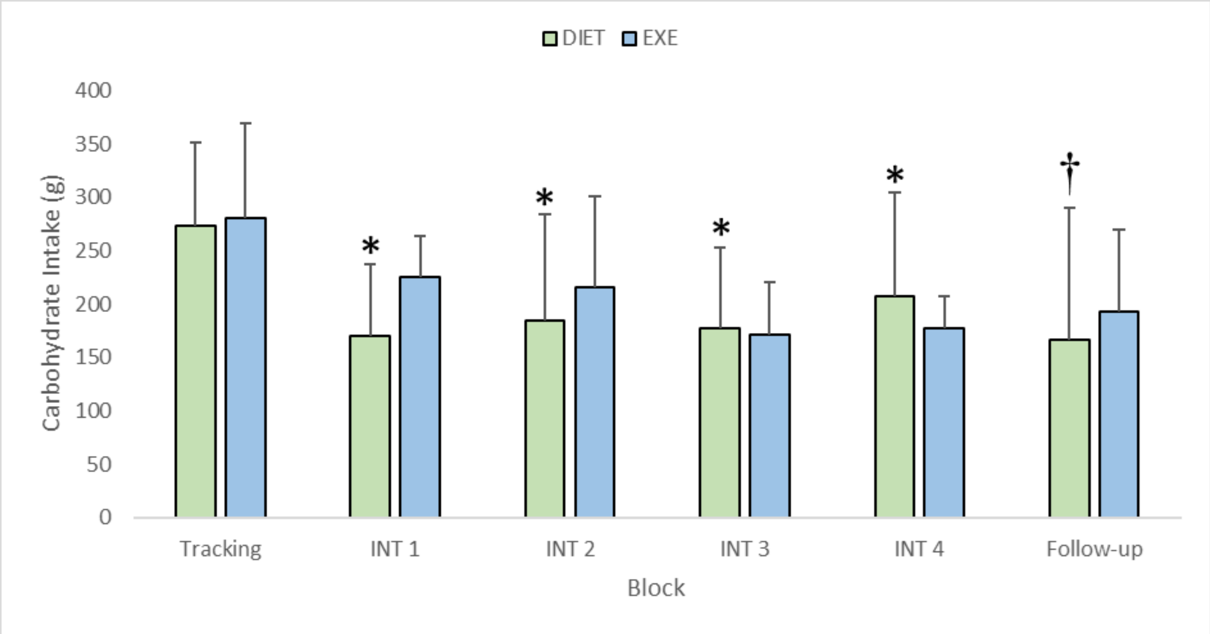

Figure 5.12 Mean (1SD) carbohydrate intake in diet and exercise groups. Abbreviations*:* INT 1-4, intervention blocks 1-4. * indicates significant decrease ($p<0.05$) from tracking. † indicates significant decrease ($p<0.05$) from INT 4.

5.3.4.2.2.3.6 Protein

Mixed: There was no significant difference in protein intake over time (main effect of time; F (5,50) = 2.072; p = 0.084) with the data from both groups combined, but there was a significant difference in protein intake between the diet and exercise groups (main effect of group; F (1,10) = 8.220; p = 0.017) irrespective of measurement time. The pattern of change in protein intake was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (5,50) = 1.022; p = 0.415).

Within: In the diet group, daily protein intake decreased from 83.72 ± 28.65g in the tracking period to 64.82 ± 34.70g in intervention block 4 and 55.67 ± 19.77g in the follow-up period. In the exercise group, daily protein intake decreased from 79.26 ± 24.82g in the tracking period to 66.84 ± 26.81g in intervention block 4 and 56.82 ± 28.62g in the follow-up period. There was a significant effect of time on total protein intake in the diet group ($\chi2$ (5) = 11.730; p =

0.039), but not in the exercise group (χ2 (5) = 6.048; p = 0.302). The significant post-hoc findings for the diet group were: Block 1 vs 2: Z = -2.613 p = .009 r = -0.67: medium; Block 1 vs 3: Z = -3.181 p = .001 r = -0.82: large; and Block 1 vs 4: Z = -3.180 p = .001 r = -0.88: large; Figure 5.13.

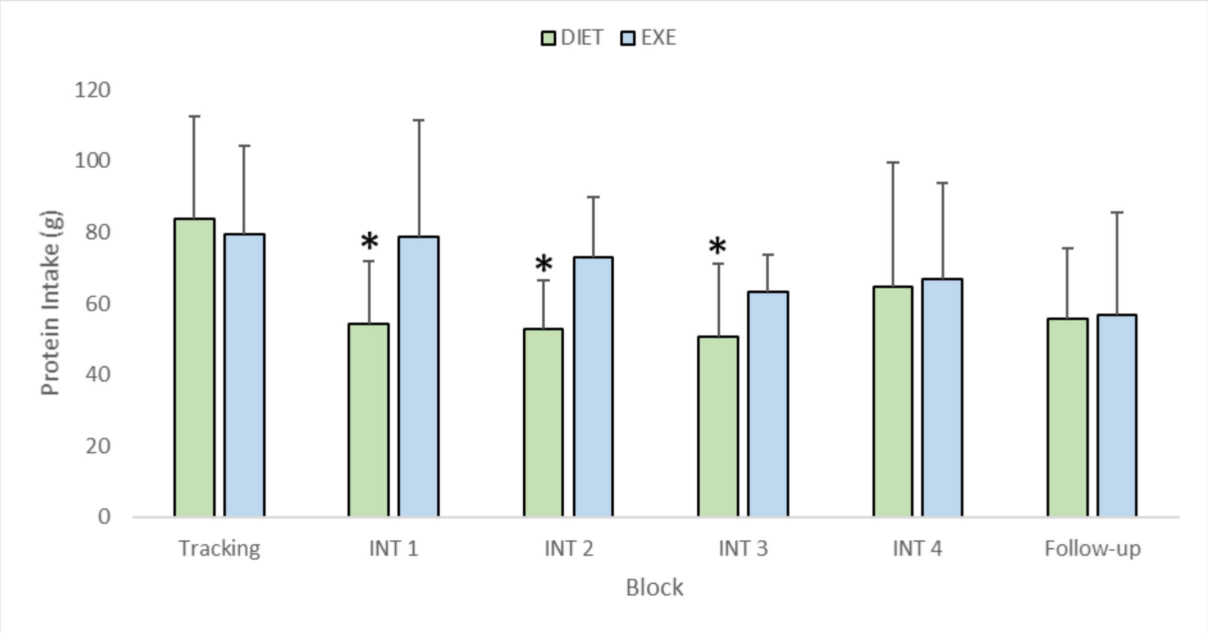

Figure 5.13 Mean (1SD) protein intake in diet and exercise groups. Abbreviations*:* INT 1-4, intervention blocks 1-4. * indicates significant decrease ($p<0.05$) from tracking.

5.3.4.2.2.4 Three Factor Eating Questionnaire

5.3.4.2.2.4.1 Uncontrolled Eating

Mixed: There was a significant difference in uncontrolled eating (UE) over time (main effect of time; F (6,108) = 14.747; p = 0.000) with the data from both groups combined, but no significant difference in UE between the diet and exercise groups (main effect of group; F (1,18) = 2.014; p = 0.173) irrespective of measurement time. The pattern of change in UE was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,108) = 0.946; p = 0.465).

Within: In the diet group, UE scores decreased from 25.41 ± 4.03 at baseline to 19.46 ± 4.14 at post-intervention and 19.75 ± 3.65 at follow-up. In the exercise group, UE scores decreased from 21.80 ± 3.49 at baseline to 19.25 ± 5.28 at post-intervention and 17.50 ± 4.17 at follow-up. There was a significant effect of time on UE in the diet group (F (6,66) = 11.923; p = 0.000) and the exercise group (χ2 (6) = 21.556; p = 0.001); Table 5.10 and 5.11.

Table 5.10 Significant post-hoc uncontrolled eating results from the Three Factor Eating Questionnaire in the diet group.

Pair	Mean ± SD	Mean ± SD	Bias-corrected and accelerated 95% confidence interval	T statistic	Degrees of freedom	*p*	*d*	
Visit 1-4	25.67 ± 4.03	21.67 ± 4.42	1.69-6.31	3.711	14	.002	0.99	Large
Visit 1-5	25.87 ± 4.02	20.73 ± 3.67	2.84-7.42	4.804	14	.000	1.28	Large
Visit 1-6	25.15 ± 3.56	19.46 ± 4.14	3.15-8.24	4.874	12	.000	1.60	Large
Visit 1-7	25.00 ± 3.67	19.75 ± 3.65	2.84-7.66	4.795	11	.001	1.43	Large
Visit 2-3	26.59 ± 4.14	23.65 ± 4.95	1.07-4.82	3.324	16	.004	0.71	Medium
Visit 2-4	26.60 ± 4.39	21.67 ± 4.42	2.29-7.58	4.003	14	.001	1.12	Large
Visit 2-5	26.47 ± 4.41	20.73 ± 3.67	3.43-8.04	5.331	14	.000	1.30	Large
Visit 2-6	26.08 ± 4.33	19.46 ± 4.14	4.09-9.14	5.714	12	.000	1.53	Large
Visit 2-7	26.17 ± 4.51	19.75 ± 3.65	3.62-9.21	5.052	11	.000	1.42	Large
Visit 3-4	23.67 ± 5.29	21.67 ± 4.42	.261-3.74	2.467	14	.027	0.38	Small
Visit 3-5	23.60 ± 5.28	20.73 ± 3.67	.938-4.79	3.189	14	.007	0.54	Medium
Visit 3-6	22.92 ± 5.11	19.46 ± 4.14	1.29-5.63	3.470	12	.005	0.68	Medium
Visit 3-7	23.00 ± 5.33	19.75 ± 3.65	.917-5.58	3.067	11	.011	0.61	Medium

Table 5.11 Significant post-hoc uncontrolled eating results from the Three Factor Eating Questionnaire in the exercise group.

			Test statistics			
Pair	Median (IQR)	Median (IQR)	*Z*	*p*	*r*	
Visit 1-5	20.00 (4.56)	18.00 (6.00)	-2.383	.012	-0.84	Large
Visit 1-6	20.00 (4.56)	18.50 (4.75)	-1.869	.012	-0.66	Medium
Visit 1-7	20.00 (4.56)	17.00 (8.25)	-2.380	.012	-0.84	Large
Visit 2-5	23.00 (6.25)	18.00 (6.00)	-2.533	.012	-0.90	Large
Visit 2-6	23.00 (6.25)	18.50 (4.65)	-1.609	.012	-0.57	Medium
Visit 2-7	23.00 (6.25)	17.00 (8.25)	-2.524	.012	-0.89	Large
Visit 3-5	21.50 (6.25)	18.00 (6.00)	-2.041	.012	-0.72	Medium
Visit 3-6	21.50 (6.25)	18.50 (4.65)	-.422	.012	-0.15	Small
Visit 3-7	21.50 (6.25)	17.00 (8.25)	-2.214	.012	-0.78	Medium
Visit 4-5	20.00 (8.00)	18.00 (6.00)	-.948	.017	-0.34	Small
Visit 4-6	20.00 (8.00)	18.50 (4.75)	-.211	.017	-0.07	Small
Visit 4-7	20.00 (8.00)	17.00 (8.25)	-2.226	.012	-0.80	Large

5.3.4.2.2.4.2 Uncontrolled Eating Percentage Expression

Mixed: There was a significant difference in percentage expression of UE scores over time (main effect of time; F (6,108) = 14.114; p = 0.000) with the data from both groups combined, but no significant difference in percentage expression of UE scores between the diet and exercise groups (main effect of group; F (1,18) = 2.064; p = 0.168) irrespective of measurement time. The pattern of change in percentage expression of UE was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,108) = 1.151; p = 0.338).

Within: In the diet group, percentage expression of UE scores decreased from 60.78 ± 14.93% at baseline to 38.75 ± 15.32% at post-intervention and 39.81 ± 13.50% at follow-up. In the exercise group, percentage expression of UE scores decreased from 47.41 ± 12.92% at baseline to 37.96 ± 19.57% at post-intervention and 31.48 ± 15.46% at follow-up. There was a significant effect of time on percentage expression of UE in the diet group (F (6,66) = 11.935; p = 0.000) and in the exercise group (F (6,42) = 4.719; p = 0.001); Table 5.12 and 5.13.

Table 5.12 Significant post-hoc percentage expression of uncontrolled eating results from the Three Factor Eating Questionnaire in the diet group.

Pair	Mean ± SD	Mean ± SD	Bias-corrected and accelerated 95% confidence interval	T statistic	Degrees of freedom	*p*	*d*	
Visit 1-4	61.75 ± 14.94	46.91 ± 16.39	6.27-23.41	3.712	14	.002	0.78	Medium
Visit 1-5	62.49 ± 14.89	43.43 ± 13.62	10.56-27.55	4.809	14	.000	1.07	Large
Visit 1-6	59.85 ± 13.19	38.73 ± 15.33	11.68-30.56	4.873	12	.000	1.24	Large
Visit 1-7	59.28 ± 13.61	39.80 ± 13.53	10.53-28.42	4.793	11	.001	1.17	Large
Visit 2-3	65.16 ± 15.33	54.25 ± 18.35	3.96-17.87	3.327	16	.004	0.54	Medium
Visit 2-4	65.21 ± 16.26	46.91 ± 16.39	8.50-28.10	4.007	14	.001	0.92	Large
Visit 2-5	64.71 ± 16.32	43.43 ± 13.62	12.73-19.83	5.341	14	.000	1.12	Large
Visit 2-6	63.27 ± 16.04	38.73 ± 15.33	15.20-33.88	5.723	12	.000	1.27	Large
Visit 2-7	63.60 ± 16.71	39.80 ± 13.53	13.44-34.16	5.055	11	.000	1.24	Large
Visit 3-4	54.31 ± 19.60	46.91 ± 16.39	.960-13.85	2.464	14	.027	0.32	Small
Visit 3-5	54.07 ± 19.56	43.43 ± 13.62	3.49-17.78	3.192	14	.007	0.49	Small
Visit 3-6	51.55 ± 18.94	38.73 ± 15.33	4.76-20.88	3.466	12	.005	0.59	Medium
Visit 3-7	51.84 ± 19.75	39.80 ± 13.53	3.39-20.69	3.062	11	.011	0.55	Medium

Table 5.13 Significant post-hoc percentage expression of uncontrolled eating results from the Three Factor Eating Questionnaire in the exercise group.

			Test statistics			
Pair	Median (IQR)	Median (IQR)	*Z*	*p*	*r*	
Visit 1-5	40.74 (16.87)	33.33 (22.22)	-2.380	.017	-0.84	Large
Visit 1-7	40.74 (16.87)	29.63 (30.56)	-2.380	.017	-0.84	Large
Visit 2-3	48.15 (19.44)	42.59 (20.37)	-2.201	.028	-0.70	Medium
Visit 2-4	51.85 (22.22)	40.74 (29.63)	-2.395	.017	-0.80	Large
Visit 2-5	51.85 (23.15)	33.33 (22.22)	-2.524	.012	-0.89	Large
Visit 2-6	51.85 (23.15)	35.19 (17.59)	-1.609	.012	-0.57	Medium
Visit 2-7	51.85 (23.15)	29.63 (30.56)	-2.521	.012	-0.89	Large
Visit 3-5	46.30 (23.15)	33.33 (22.22)	-2.032	.042	-0.72	Medium
Visit 3-7	46.30 (23.15)	29.63 (30.56)	-2.207	.027	-0.78	Medium

5.3.4.2.2.4.3 Cognitive Restraint

Mixed: There was a significant difference in cognitive restraint (CR) scores over time (main effect of time; $F(6,108) = 20.537$; $p = 0.000$) with the data from both groups combined, but no significant difference in CR scores between the diet and exercise groups (main effect of group; $F(1,18) = 0.489$; $p = 0.493$) irrespective of measurement time. The pattern of change in CR scores was similar [no significant differences] between the diet and exercise groups (group x time interaction; $F(6,108) = 1.642$; $p = 0.187$).

Within: In the diet group, CR scores increased from 13.59 ± 2.79 at baseline to 19.23 ± 2.20 at post-intervention and 18.42 ± 2.54 at follow-up. In the exercise group, CR scores increased from 14.30 ± 3.09 at baseline to 18.75 ± 3.99 at post-intervention and 18.88 ± 3.48 at follow-up. There was a significant effect of time on CR in the diet group ($F(6,66) = 15.360$; $p = 0.000$) and in the exercise group ($F(6,42) = 8.646$; $p = 0.001$); Table 5.14 and 5.15.

Table 5.14 Significant post-hoc cognitive restraint results from the Three Factor Eating Questionnaire in the diet group.

			Test statistics			
Pair	**Median (IQR)**	**Median (IQR)**	***Z***	***p***	***r***	
Visit 1-3	14.00 (5.00)	17.00 (6.00)	-2.556	.010	-0.62	Medium
Visit 1-4	14.00 (5.00)	20.00 (5.00)	-3.450	.001	-0.86	Large
Visit 1-5	14.00 (4.00)	19.00 (2.00)	-3.413	.001	-0.88	Large
Visit 1-6	14.00 (4.00)	19.00 (5.75)	-3.063	.002	-0.85	Large
Visit 1-7	14.00 (4.25)	18.00 (4.75)	-3.066	.002	-0.89	Large
Visit 2-3	14.00 (4.00)	17.00 (6.00)	-3.068	.002	-0.74	Medium
Visit 2-4	14.00 (3.50)	20.00 (5.00)	-3.521	.000	-0.88	Large
Visit 2-5	14.00 (4.00)	19.00 (2.00)	-3.415	.001	-0.88	Large
Visit 2-6	14.00 (5.00)	19.00 (1.00)	-3.063	.002	-0.85	Large
Visit 2-7	13.50 (5.25)	18.00 (4.25)	-3.063	.002	-0.88	Large
Visit 5-7	19.50 (4.00)	18.00 (4.25)	-2.214	.027	-0.64	Medium

Table 5.15 Significant post-hoc cognitive restraint results from the Three Factor Eating Questionnaire in the exercise group.

Pair	**Mean ± SD**	**Mean ± SD**	**Bias-corrected and accelerated 95% confidence interval**	**T statistic**	**Degrees of freedom**	***p***	***d***	
Visit 1-4	14.22 ± 3.27	16.11 ± 3.22	-4.56-.786	-1.628	8	.002	-0.47	Small
Visit 1-5	14.63 ± 3.25	18.56 ± 2.53	-6.85--1.02	-3.192	7	.000	-1.11	Large
Visit 1-6	14.63 ± 3.25	18.75 ± 3.99	-8.54-.286	-2.211	7	.000	-0.96	Large
Visit 1-7	14.63 ± 3.25	18.88 ± 3.48	-7.62-.884	-2.985	7	.001	-1.04	Large
Visit 2-3	12.80 ± 2.90	15.40 ± 1.26	-4.39- -.809	-3.284	9	.004	-0.86	Large
Visit 2-4	12.67 ± 3.04	16.11 ± 3.22	-5.12--1.76	-4.727	8	.001	-0.91	Large
Visit 2-5	12.88 ± 3.18	18.56 ± 2.53	-7.89--3.49	-6.113	7	.000	-1.56	Large
Visit 2-6	12.88 ± 3.18	18.75 ± 3.99	-9.54--2.21	-3.786	7	.000	-1.38	Large
Visit 2-7	12.88 ± 3.18	18.88 ± 3.48	-8.49--3.51	-5.702	7	.000	-1.49	Large
Visit 3-4	15.56 ± 1.24	16.11 ± 3.22	-2.63-1.52	-.618	8	.027	-0.21	Small
Visit 3-5	15.50 ± 1.31	18.56 ± 2.53	-4.71--1.41	-4.393	7	.007	-1.38	Large
Visit 3-6	15.50 ± 1.31	18.75 ± 3.99	-6.68-.175	-2.244	7	.005	-1.04	Large
Visit 3-7	15.50 ± 1.31	18.88 ± 3.48	-5.86-.889	-3.211	7	.011	-1.21	Large

5.3.4.2.2.4.4 Cognitive Restraint Percentage Expression

Mixed: There was a significant difference in percentage expression of CR over time (main effect of time; F (6,108) = 20.422; p = 0.000) with the data from both groups combined, but no significant difference in percentage expression of CR between the diet and exercise groups (main effect of group; F (1,18) = 0.502; p = 0.488) irrespective of measurement time. The pattern of change in percentage expression of CR was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,108) = 1.647; p = 0.185).

Within: In the diet group, percentage expression of CR scores increased from 37.94 ± 13.93% at baseline to 66.15 ± 11.02% at post-intervention and 62.08 ± 12.70% at follow-up. In the exercise group, percentage expression of CR scores increased from 41.50 ± 15.47% at baseline to 63.75 ± 19.96% at post-intervention and 64.38 ± 17.41% at follow-up. There was a significant effect of time on percentage expression of CR in the diet group (F (6,66) = 15.360; p = 0.000) and in the exercise group (F (6,42) = 8.542; p = 0.000); Table 5.16 and Table 5.17.

Table 5.16 Significant post-hoc percentage expression of cognitive restraint results from the Three Factor Eating Questionnaire in the diet group.

			Test statistics			
Pair	**Median (IQR)**	**Median (IQR)**	***Z***	***p***	***r***	
Visit 1-3	40.00 (25.00)	55.00 (30.00)	-2.556	.010	-0.62	Medium
Visit 1-4	40.00 (25.00)	70.00 (25.00)	-3.450	.001	-0.86	Large
Visit 1-5	40.00 (20.00)	65.00 (10.00)	-3.413	.001	-0.88	Large
Visit 1-6	40.00 (20.00)	65.00 (5.00)	-3.063	.002	-0.85	Large
Visit 1-7	40.00 (21.25)	60.00 (21.25)	-3.066	.002	-0.89	Large
Visit 2-3	40.00 (20.00)	55.00 (30.00)	-3.068	.002	-0.74	Medium
Visit 2-4	40.00 (17.50)	70.00 (25.00)	-3.521	.000	-0.88	Large
Visit 2-5	40.00 (20.00)	65.00 (10.00)	-3.415	.001	-0.88	Large
Visit 2-6	40.00 (25.00)	65.00 (5.00)	-3.063	.002	-0.85	Large
Visit 2-7	37.50 (26.25)	60.00 (21.25)	-3.063	.002	-0.88	Large
Visit 5-7	67.50 (20.00)	60.00 (21.25)	-2.214	.027	-0.64	Medium

Table 5.17 Significant post-hoc percentage expression of cognitive restraint results from the Three Factor Eating Questionnaire in the exercise group.

Pair	**Mean ± SD**	**Mean ± SD**	**Bias-corrected and accelerated 95% confidence interval**	**T statistic**	**Degrees of freedom**	***p***	***d***	
Visit 1-2	41.50 ± 15.47	34.00 ± 14.49	1.84-13.16	3.000	9	.015	0.40	Small
Visit 1-5	43.13 ± 16.24	62.88 ± 12.61	-34.24- -5.26	-3.222	7	.015	-1.07	Large
Visit 1-7	43.13 ± 16.24	64.38 ± 17.41	-38.08- -4.42	-2.985	7	.020	-1.04	Large
Visit 2-3	34.00 ± 14.49	47.00 ±6.32	-21.95- -4.05	-3.284	9	.009	-0.86	Large
Visit 2-4	33.33 ± 15.21	50.56 ± 16.09	-25.62- -8.82	-4.727	8	.001	-0.91	Large
Visit 2-5	34.38 ± 15.91	62.88 ± 12.61	-39.43- -17.57	-6.167	7	.000	-1.56	Large
Visit 2-6	34.38 ± 15.91	63.75 ± 19.96	-47.72- -11.03	-3.786	7	.007	-1.38	Large
Visit 2-7	34.38 ± 15.91	64.38 ± 17.41	-42.44- -17.56	-5.702	7	.001	-1.49	Large
Visit 3-5	47.50 ±6.55	62.88 ± 12.61	-23.60- -7.15	-4.419	7	.003	-1.39	Large
Visit 3-7	47.50 ±6.55	64.38 ± 17.41	-29.30- -4.45	-3.211	7	.015	-1.21	Large
Visit 4-5	52.50 ± 16.04	62.88 ± 12.61	-19.19- -1.56	-2.784	7	.027	-0.57	Large

5.3.4.2.2.4.5 Emotional Eating

Mixed: There was a significant difference in emotional eating (EE) over time (main effect of time; F (6,108) = 5.911; p = 0.001) with the data from both groups combined, but no significant difference in EE between the diet and exercise groups (main effect of group; F (1,18) = 2.348; p = 0.143) irrespective of measurement time. The pattern of change in EE was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,108) = 0.404; p = 0.784).

Within: In the diet group, EE scores decreased from 9.12 ± 2.15 at baseline to 6.92 ± 1.89 at post-intervention and 7.00 ± 1.81 at follow-up. In the exercise group, EE scores decreased from 7.50 ± 1.35 at baseline to 6.25 ± 2.25 at post-intervention and 5.75 ± 2.25 at follow-up. There was a significant effect of time on EE in the diet group (χ2 (6) = 23.966; p = 0.001), but not the exercise group (F (6,42) = 1.919; p = 0.100); Table 5.18.

Table 5.18 Significant post-hoc emotional eating results from the Three Factor Eating Questionnaire in the diet group.

			Test statistics			
Pair	**Median (IQR)**	**Median (IQR)**	***Z***	***p***	***r***	
Visit 1-3	9.00 (3.00)	9.00 (4.00)	-2.138	.033	-0.52	Medium
Visit 1-4	9.00 (2.25)	8.00 (2.25)	-2.422	.015	-0.61	Medium
Visit 1-5	9.00 (2.50)	8.00 (3.00)	-2.694	.007	-0.70	Medium
Visit 1-6	9.00 (2.00)	7.00 (2.00)	-2.390	.017	-0.66	Medium
Visit 1-7	9.00 (2.50)	7.00 (2.25)	-2.464	.014	-0.71	Medium
Visit 2-3	9.00 (2.00)	9.00 (4.00)	-2.066	.039	-0.50	Medium
Visit 2-4	9.00 (2.25)	8.00 (2.25)	-2.436	.015	-0.61	Medium
Visit 2-5	9.00 (2.50)	8.00 (3.00)	-2.583	.007	-0.67	Medium
Visit 2-6	9.00 (3.00)	7.00 (2.00)	-2.537	.011	-0.70	Medium
Visit 2-7	9.00 (3.25)	7.00 (2.25)	-2.701	.007	-0.78	Medium
Visit 3-5	8.50 (3.00)	8.00 (3.00)	-2.209	.027	-0.57	Medium
Visit 3-7	9.00 (4.00)	7.00 (2.25)	-2.203	.028	-0.64	Medium

5.3.4.2.2.4.6 Emotional Eating Percentage Expression

Mixed: There was no significant difference in percentage expression of EE over time (main effect of time; F (6,108) = 3.502; p = 0.064) with the data from both groups combined and no significant difference in percentage expression of EE between the diet and exercise groups (main effect of group; F (1,18) = 0.960; p = 0.340) irrespective of measurement time. The pattern of change in percentage expression of EE was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,108) = 1.148; p = 0.312).

Within: In the diet group, percentage expression of EE scores decreased from 67.97 ± 23.86% at baseline to 43.59 ± 21.01% at post-intervention and 44.44 ± 20.10% at follow-up. In the exercise group, percentage expression of EE scores decreased from 50.00 ± 15.04% at baseline to 36.11 ± 25.02% at post-intervention and 30.56 ± 25.02% at follow-up. There was a significant effect of time on percentage expression of EE in the diet group ($\chi 2$ (6) = 23.966; p = 0.001), but not in the exercise group (F (6,42) = 1.913; p = 0.101). Table 5.19 shows the significant post-hoc findings in the diet group.

Table 5.19 Significant post-hoc Emotional Eating Percentage Expression scores from the Three Factor Eating Questionnaire in the diet group.

			Test statistics			
Pair	**Median (IQR)**	**Median (IQR)**	***Z***	***p***	***r***	
Visit 1-3	66.67 (33.33)	66.67 (44.44)	-2.234	.025	-0.54	Medium
Visit 1-4	66.67 (25.00)	55.56 (25.00)	-2.400	.016	-0.60	Medium
Visit 1-5	66.67 (27.78)	55.56 (33.33)	-2.743	.006	-0.71	Medium
Visit 1-6	66.67 (22.22)	44.44 (22.22)	-2.452	.014	-0.68	Medium
Visit 1-7	66.67 (27.78)	44.44 (25.00)	-2.486	.013	-0.72	Medium
Visit 2-3	66.67 (22.22)	66.67 (44.44)	-2.066	.039	-0.50	Medium
Visit 2-4	66.67 (25.00)	55.56 (25.00)	-2.348	.019	-0.58	Medium
Visit 2-5	66.67 (27.78)	55.56 (33.33)	-2.675	.007	-0.69	Medium
Visit 2-6	66.67 (33.33)	44.44 (22.22)	-2.537	.011	-0.70	Medium
Visit 2-7	66.67 (36.11)	44.44 (25.00)	-2.694	.007	-0.78	Medium
Visit 3-5	61.11 (33.33)	55.56 (33.33)	-2.254	.025	-0.58	Medium
Visit 3-6	55.60 (44.44)	44.44 (22.22)	-1.965	.049	-0.54	Medium
Visit 3-7	66.67 (44.44)	44.44 (25.00)	-2.198	.028	-0.63	Medium

5.3.4.2.3 Emotional Health & Wellbeing Measures

5.3.4.2.3.1 Short-Form 36

One participant (P06) did not complete the SF-36 questionnaire at visit 2. The SF-36 questionnaire is split into 'physical functioning', 'role limitations due to physical health', 'role limitations due to emotional problems', 'energy/fatigue', 'emotional wellbeing', 'social functioning', 'pain' and 'general health' constructs.

5.3.4.2.3.1.1 Physical Functioning

Mixed: There was a significant difference in physical functioning over time (main effect of time; F (6,102) = 9.984; p = 0.000) with the data from both groups combined, but no significant difference in physical functioning between the diet and exercise groups (main effect of group; F (1,17) = 2.011; p = 0.174) irrespective of measurement time. The pattern of change in physical functioning was different between the diet and exercise groups (group x time interaction; F (6,102) = 3.097; p = 0.044).

Within: In the diet group, physical functioning scores increased from 88.53 ± 17.39 at baseline to 98.46 ± 3.15 at post-intervention and 99.58 ± 1.44 at follow-up. In the exercise group, physical functioning scores increased from 83.00 ± 17.67 at baseline to 96.25 ± 8.76 at post-intervention and 96.88 ± 7.04 at follow-up. There was a significant effect of time on physical functioning in the diet group ($\chi 2$ (6) = 24.527; p = 0.000) and exercise group ($\chi 2$ (6) = 26.797; p = 0.000). Post hoc analysis showed significantly higher physical functioning scores in the diet group between the following visits; visit 1 & 4 (*Z* = -2.539; p = .011; *r* = -059; medium); visit 1 & 6 (*Z* = -2.263; p = .024; *r* = -0.63; medium); visit 1 & 7 (*Z* = -2.226; p = .026; *r* = -0.64; medium); visit 2 & 4 (*Z* = -2.506; p = .012; *r* = -0.63; medium); visit 2 & 5 (*Z* = -2.410; p = .016; *r* = -0.62; medium); visit 2 & 6 (*Z* = -2.388; p = .017; *r* = -0.66; medium); visit 2 & 7 (*Z* = -2.388; p = .017; *r* = -0.69; medium); and visit 3 & 4 (*Z* = -2.023; p = .043; *r* = -0.51; medium). In the exercise group, significant increases in physical functioning were shown between visit 1 and visits 2, 3, 4, 5, 6 and 7, and between visit 2 and visits 5, 6 and 7 (Table 5.20). There were also increases in physical functioning between visit 3 and 7, and between visit 4 and visits 6 and 7.

Table 5.20 Significant post-hoc physical functioning scores from the Short-Form 36 Questionnaire in the exercise group.

			Test statistics			
Pair	**Median (IQR)**	**Median (IQR)**	***Z***	***p***	***r***	
Visit 1-2	85.00 (25.00)	95.00 (0.00)	-2.132	.033	-0.71	Medium
Visit 1-3	85.00 (25.00)	95.00 (5.00)	-2.120	.034	-0.67	Medium
Visit 1-4	85.00 (30.00)	95.00 (5.00)	-2.041	.041	-0.68	Medium
Visit 1-5	85.00 (21.25)	100.00 (2.50)	-2.232	.026	-0.79	Medium
Visit 1-6	85.00 (21.25)	100.00 (1.25)	-2.226	.026	-0.79	Medium
Visit 1-7	85.00 (21.25)	100.00 (1.25)	-2.226	.026	-0.79	Medium
Visit 2-5	95.00 (7.50)	100.00 (2.50)	-2.121	.034	-0.80	Large
Visit 2-6	95.00 (7.50)	100.00 (1.25)	-2.121	.034	-0.80	Large
Visit 2-7	95.00 (7.50)	100.00 (1.25)	-2.333	.020	-0.88	Large
Visit 3-7	95.00 (8.75)	100.00 (1.25)	-2.121	.034	-0.75	Medium
Visit 4-6	97.50 (10.00)	100.00 (1.25)	-2.121	.034	-0.75	Medium
Visit 4-7	97.50 (10.00)	100.00 (1.25)	-2.070	.038	-0.73	Medium

5.3.4.2.3.1.2 Role Limitations due to Physical Health

Mixed: There was no significant difference in role limitations due to physical health over time (main effect of time; F (6,84) = 1.582; p = 0.220) with the data from both groups combined and no significant difference in role limitations due to physical health between the diet and exercise groups (main effect of group; F (1,14) = 0.278; p = 0.606) irrespective of measurement time. The pattern of change in role limitations due to physical health was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,84) = 0.421; p = 0.684).

Within: In the diet group, role limitations due to physical health scores increased from 86.76 ± 28.11 at baseline to 100.00 ± 0.00 at post-intervention and 100.00 ± 0.00 at follow-up. In the exercise group, role limitations due to physical health scores increased from 92.50 ± 16.87 at baseline to 100.00 ± 0.00 at post-intervention and 100.00 ± 0.00 at follow-up. There was no significant effect of time on role limitations due to physical health in the diet group ($\chi 2$ (6) = 8.667; p = 0.193) or exercise group ($\chi 2$ (6) = 5.576; p = 0.472).

5.3.4.2.3.1.3 Role Limitations due to Emotional Health

Mixed: There was no significant difference in role limitations due to emotional health over time (main effect of time; F (6,102) = 1.480; p = 0.240) with the data from both groups combined and no significant difference in role limitations due to emotional health between the diet and exercise groups (main effect of group; F (1,17) = 0.400; p = 0.536) irrespective of measurement time. The pattern of change in role limitations due to emotional health was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,102) = 1.056; p = 0.365).

Within: In the diet group, role limitations due to emotional health scores increased from 94.12 ± 17.62 at baseline to 100.00 ± 0.00 at post-intervention and 100.00 ± 0.00 at follow-up. In the exercise group, role limitations due to emotional health scores increased from 83.33 ± 32.39 at baseline to 100.00 ± 0.00 at post-intervention and 100.00 ± 0.00 at follow-up. There was no significant effect of time on role limitations due to emotional problems in the diet group ($\chi 2$ (6) = 5.000; p = 0.544) or exercise group ($\chi 2$ (6) = 8.667; p = 0.193).

5.3.4.2.3.1.4 Energy/Fatigue

Mixed: There was a significant difference in energy/fatigue over time (main effect of time; F (6,102) = 4.264; p = 0.005) with the data from both groups combined, but no significant difference in energy/fatigue between the diet and exercise groups (main effect of group; F

(1,17) = 0.499; p = 0.489) irrespective of measurement time. The pattern of change in energy/fatigue was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,102) = 1.408; p = 0.219).

Within: In the diet group, energy/fatigue scores increased from 49.71 ± 20.19 at baseline to 62.69 ± 11.48 at post-intervention and 62.50 ± 16.58 at follow-up. In the exercise group, energy/fatigue scores increased from 45.50 ± 17.39 at baseline to 65.00 ± 13.36 at post-intervention and 65.63 ± 5.63 at follow-up. There was a significant effect of time on energy/fatigue in the diet group (F (6,66) = 2.655; p = 0.023), but not in the exercise group ($\chi 2$ (6) = 12.335; p = 0.055). Post hoc analysis showed significantly higher energy/fatigue scores in the diet group between visits 1 & 4 (t(8), -2.195; p = .044; BCa 95% CI -19.09 - -.282 *d* =-0.43; small) and visits 2 & 4 (t(15), -2.425; p = .028; BCa 95% CI -15.27 - -.984 *d* =-0.47; small).

5.3.4.2.3.1.5 Emotional Wellbeing

Mixed: There was no significant difference in wellbeing over time (main effect of time; F (6,102) = 1.399; p = 0.222) with the data from both groups combined and no significant difference in wellbeing between the diet and exercise groups (main effect of group; F (1,17) = 2.166; p = 0.159) irrespective of measurement time. The pattern of change in wellbeing was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,102) = 0.695; p = 0.553).

Within: In the diet group, emotional wellbeing scores increased from 77.88 ± 15.11 at baseline to 87.69 ± 5.53 at post-intervention and 86.67 ± 7.30 at follow-up. In the exercise group, emotional wellbeing scores increased from 80.00 ± 5.66 at baseline to 81.50 ± 5.63 at post-intervention and 82.50 ± 7.39 at follow-up. There was no significant effect of time on emotional wellbeing in the diet group ($\chi2$ (6) = 8.846; p = 0.182) or exercise group ($\chi2$ (6) = 1.871; p = 0.931).

5.3.4.2.3.1.6 Social Functioning

Mixed: There was no significant difference in social functioning over time (main effect of time; F (6,102) = 0.877; p = 0.450) with the data from both groups combined and no significant difference in social functioning between the diet and exercise groups (main effect of group; F (1,17) = 0.164; p = 0.690) irrespective of measurement time. The pattern of change in social functioning was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,102) = 1.118; p = 0.348).

Within: In the diet group, social functioning scores increased from 91.18 ± 18.63 at baseline to 100.00 ± 0.00 at post-intervention and 98.96 ± 3.61 at follow-up. In the exercise group, social functioning scores increased from 93.75 ± 10.62 at baseline to 98.44 ± 4.42 at post-intervention and 98.44 ± 4.42 at follow-up. There was no statistically significant effect of time on social functioning in the diet group ($\chi2$ (6) = 5.324; p = 0.503) or in the exercise group ($\chi2$ (6) = 7.514; p = 0.276).

5.3.4.2.3.1.7 Pain

Mixed: There was no significant difference in pain over time (main effect of time; F (6,102) = 1.981; p = 0.126) with the data from both groups combined and no significant difference in pain between the diet and exercise groups (main effect of group; F (1,17) = 0.533; p = 0.475) irrespective of measurement time. The pattern of change in pain was similar [no significant differences] between the diet and exercise groups (group x time interaction; $F(6,102) = 0.664$; $p = 0.583$).

Within: In the diet group, pain scores increased from 82.35 ± 15.22 at baseline to 93.65 ± 11.84 at post-intervention and 93.96 ± 9.62 at follow-up. In the exercise group, pain scores increased from 85.25 ± 18.08 at baseline to 89.06 ± 23.90 at post-intervention and 92.19 ± 14.73 at follow-up. There was a significant effect of time on pain in the diet group ($\chi2$ (6) = 13.574; p = 0.035), but not in the exercise group ($\chi2$ (6) = 3.422; p = 0.754). The significant post-hoc findings for the diet group were; Visit 1 vs 4: Z = -2.166 p = .030 r =-0.54: medium; Visit 1 vs 6: Z = -2.354 p = .019 r = -0.65: medium; and Visit 1 vs 7: Z = -2.565 p = .010 r = -0.74: medium.

5.3.4.2.3.1.8 General Health

Mixed: There was a significant difference in general health over time (main effect of time; F (6,102) = 5.726; p = 0.001) with the data from both groups combined, but no significant difference in general health between the diet and exercise groups (main effect of group; F (1,17) = 0.009; p = 0.925) irrespective of measurement time. The pattern of change in general health was similar [no significant differences] between the diet and exercise groups (group x time interaction; F (6,102) = 1.157; p = 0.336).

Within: In the diet group, general health scores increased from 67.35 ± 15.92 at baseline to 80.29 ± 14.62 at post-intervention and 77.92 ± 12.15 at follow-up. In the exercise group, general health scores increased from 66.50 ± 19.30 at baseline to 81.25 ± 17.03 at post-intervention and 76.88 ± 19.63 at follow-up. There was a significant effect of time on general health in the diet group (F (6,66) = 3.379; p = 0.006), but not in the exercise group (F (6,66) = 3.379; p = 0.006). Post-hoc analysis showed significant increases in general health scores in the diet group between the following visits; visits 1 and 6 (t(12), -2.366; p = .036; BCa 95% CI -20.50-.845; *d* =-0.58; moderate); visits 2 and 3 (t(16), -2.889; p = .011; BCa 95% CI -9.28- -1.42; *d* =-0.29; small); visits 2 and 6 (t(12), -2.926; p = .013; BCa 95% CI -20.63- -3.02; *d* =-0.70; moderate); and visits 5 and 6 (t(12), -2.424; p = .032; BCa 95% CI -15.88-.847; *d* =-0.48; small).

5.3.4.2.3.2 Pittsburgh Sleep Quality Index

Mixed: There was a significant difference in PSQI score over time (main effect of time; $F_{(6,108)} = 4.646$; $p = 0.000$) with the data from both groups combined, but no significant difference in PSQI score between the diet and exercise groups (main effect of group; $F_{(1,18)} = 0.306$; $p = 0.587$) irrespective of measurement time. The pattern of change in global PSQI score was similar [no significant differences] between the diet and exercise groups (group x time interaction; $F_{(6,108)} = 0.993$; $p = 0.434$).

Within: In the diet group, PSQI scores decreased from 7.47 ± 2.85 at baseline to 4.62 ± 2.18 at post-intervention and 4.08 ± 2.81 at follow-up. In the exercise group, PSQI scores decreased from 7.90 ± 3.87 at baseline to 4.63 ± 1.60 at post-intervention and 5.25 ± 3.11 at follow-up. There was a significant effect of time on PSQI scores in the diet group (χ^2 (6) = 17.206; p = 0.009), but not in the exercise group (χ^2 (6) = 7.840; p = 0.250). In the diet group, post hoc analysis showed significantly lower PSQI scores (better sleep quality) between the following visits; visit 1 & 2 (*Z* = -2.632; p = .008; *r* = -0.64; medium); visit 1 & 3 (*Z* = -2.078; p = .038; *r* = -0.50; medium); visit 1 & 4 (*Z* = -2.290; p = .022; *r* = -0.57; medium); visit 1 & 5 (*Z* = -2.525; p = .012; *r* = -0.65; medium); visit 1 & 6 (*Z* = -2.439; p = .015; *r* = -0.68; medium); and visit 1 & 7 (*Z* = -2.320; p = .020; *r* = -0.64; medium).

5.4 Discussion

This study aimed to investigate the effect of a self-selected exercise or dietary intervention on weight management [primary outcome], body composition and metabolic health, exercise and dietary behaviours, and emotional health and wellbeing [secondary outcomes] in overweight and obese postpartum women. Following the choice of engaging in a diet or exercise intervention, 17 women chose to modify diet and 10 women chose to focus on exercise.

5.4.1 Weight Management

Both the diet and exercise interventions were successful in encouraging significant (i) baseline to post-intervention and (ii) baseline to follow-up reductions in body weight, however results showed that the diet group experienced greater reductions in body weight when compared to the exercise group. In the diet group, participants experienced a 5.83 ± 3.41kg [7.54 ± 4.84%] weight loss and in the exercise group, participants experienced a 3.98 ± 2.98kg [5.17 ± 3.76%] weight loss. In the combined diet and exercise group, women experienced a 1.91 ± 1.23 $kg{\cdot}m^2$ reduction in BMI and a weight loss of 5.09 ± 3.30kg at follow-up. Fourteen of the study finishers experienced at least a 5% reduction in weight, which is considered meaningful in improving weight-related health outcomes (Wilkinson, van der Pligt, Gibbons, & McIntyre, 2015), and three participants experienced a >10% weight reduction, which is known to induce further improvements in comorbid conditions, for example, lower incidences of obstructive sleep apnoea, type 2 diabetes and depression (Ryan & Yockey, 2017).

A large portion of previous intervention studies in overweight and obese postpartum women have not resulted in significant changes in body mass or such great percentage weight loss in intervention participants from pre- to post-intervention (Falciglia, Piazza, Ollberding, Spiess, & Morrow, 2017; Gilmore et al., 2017; Østbye et al., 2009; Wilkinson et al., 2015; Wiltheiss et al., 2013). For example, Østbye et al. (2009) enrolled 450 overweight and obese women in a nine-month postpartum lifestyle intervention initiated from six weeks postpartum and showed only a 1.01% weight loss in intervention participants during this time. Similarly, Wilkinson et al. (2015) delivered a goal-setting session focused on postnatal nutrition at 36 weeks gestation followed by a correspondence intervention, requiring the return of self-monitoring information, from six to 24-weeks postpartum and showed a 0.97% weight loss in women enrolled in the intervention. Gilmore et al. (2017) described that weight was maintained during their 16-week pilot 'E-Moms' personalised health intervention delivered via a smartphone, and the intervention group (*n*= 131) enrolled in the Kids and Adults Now – Defeat Obesity (KAN-DO) 10-month RCT experienced a 2.30 ± 5.40kg weight loss compared to a 5.09 ± 3.30kg weight loss experienced by the combined diet and exercise group participants in the current study (Wiltheiss et al., 2013). The reasons for the lack of success in previous studies may be due to the generalised nature of physical activity (*e.g.*, 150 minutes per week moderate-vigorous intensity exercise; Østbye et al. (2009)) and diet (*e.g.*, consume a diet in line with the My Pyramid guide; Falciglia et al. (2017)) advice provided to participants, and the lack of face-to-face contact during the study period (Gilmore et al., 2017). The results from the current study align with previous work that, like the intervention employed herein, delivered behaviour change programmes including specific exercise (intensity and frequency) advice (Lovelady, Garner, Moreno, & Williams, 2000), elements of goal setting (Herring, Cruice, Bennett, Davey, & Foster, 2014; Lovelady et al., 2000; Nicklas et al., 2014), frequent contact via text messages and/or phone calls (Huseinovic et al., 2016; Nicklas et al., 2014), and self-monitoring of behaviour (Herring et al., 2014; Nicklas et al., 2014). The approach adopted by the current study has shown that the co-design of a lifestyle intervention and incorporation of previous efficacious behaviour change strategies has proven extremely successful in eliciting significant reductions in postpartum body mass, and other researchers and primary health care providers should look to adopt this approach with other groups of postpartum women.

5.4.2 Body Composition

In this study there was a significant change in FFM across the study period in the combined diet and exercise groups, however participants in the diet group experienced a much greater reduction in FFM compared to the exercise group. There was also a significant change in FMI in the combined diet and exercise groups, with the diet group experiencing a reduction in FMI and the exercise group experiencing an increase in FMI. There was no change in any other DXA variables. Previously, Amorim Adegboye, Linne, & Lourenco (2007) conducted a review to assess the effect of diet, exercise, or both, for encouraging weight reduction in 245 postpartum women across six trials. Secondary outcomes collected included FM% and FFM. When assessing the effect of diet interventions versus usual care, similar to the results in the current study, women allocated to a diet group lost significantly more FFM (MD -0.90kg; 95% CI -1.38- -0.42), and there was no significant difference between groups when measuring FM% (MD -0.40% BF; 95% CI -1.15-0.35). When assessing the effect of exercise interventions versus usual care there were no differences between groups in FM% (MD 0.20% BF; 95% CI -5.40-5.80) or FFM (MD 0.30kg; 95% CI -3.78-4.38), although only one study including 33 women was analysed. Bertz et al. (2012) evaluated the effect of three 12-week behaviour modification treatments; a dietary treatment to decrease energy intake, an exercise treatment to implement moderate-intensity aerobic exercise; and a combined dietary and exercise treatment, in comparison with a control group in 68 overweight and obese postpartum women. Post-intervention and 1-year follow-up data were collected; specifically, weight change, BMI change and body composition (measured by DXA scans) were recorded. Individuals in the dietary group and not the exercise group experienced a significant loss of FM at post-intervention (-6.9 ± 3.4kg vs. -1.8 ± 3.0kg; $p<0.001$), which is in agreement with the results of the current study. In the current study, the closure of laboratories as a result of the COVID-19 pandemic had an impact upon body composition assessment outcomes, as only eight of 20 women who completed the study underwent DXA scans at visits 1, 2, 6 and 7 as initially planned. The work from Amorim et al. (2007), Bertz et al. (2012), and the current study demonstrated that exercise interventions result in less favourable measures of post-intervention body composition, when compared to diet interventions. Despite substantial evidence that FMI is a more sensitive marker of obesity than BMI and FM% (De Miguel-Etayo et al., 2015; Freedman, Ogden, Berenson, & Horlick, 2005; Peltz, Aguirre, Sanderson, & Fadden, 2010), to our knowledge this is the first postpartum lifestyle intervention to collect data on FMI, however work in overweight adolescents has also shown significant reductions in FMI when coupled with weight loss (De Miguel-Etayo et al., 2015; Durá-Travé et al., 2020). Future work should further explore (i) the effect of the diet and exercise interventions delivered in the current study on body composition (including FMI) when not impacted by the COVID-19 pandemic and (ii) the design of exercise interventions, specifically the mode, intensity and frequency of prescribed exercise, to attempt to identify efficacious approaches to produce positive changes in body composition in postpartum women enrolled in exercise interventions.

5.4.3 Cardiometabolic Outcomes

Results from the current study showed significant reductions in hip girth, waist girth and bust girth measures in only the diet group. There were, however, no changes in LDL, HDL, TG, BP, or resting HR in either the diet or exercise groups. These findings agree with work by Nicklas et al. (2019) who demonstrated that a web-based lifestyle intervention (Balance after Baby) initiated around 6-weeks postpartum was not effective in improving a variety of cardiometabolic risk factors (including LDL, HDL, TG and BP), but did encourage significant weight loss at both 6 and 12-months, when compared to a control group. Nicklas et al. (2019) also showed no change in waist circumference across the study period, which does not agree with the findings from the current study. Although, post-hoc analysis by Nicklas et al. (2019) demonstrated that cardiovascular risk factors were significantly correlated with changes in both weight and waist circumference. Gilmore et al. (2017) included waist and hip circumferences, BP, and HR measures as part of a 16-week mHealth lifestyle intervention for postpartum women. Akin to the results from the current study, the authors showed no change in waist:hip ratio and BP (systolic and diastolic) in the intervention group, but, unlike the current study, the intervention was not effective in encouraging postpartum weight loss. Whilst Gilmore et al. (2017) stated that HR was measured, there was no mention of HR outcomes in the results and it appears that very little previous work has examined the effect of lifestyle interventions on resting HR in women enrolled in a postpartum lifestyle intervention, rather work has been completed to understand changes in cardiac function from pregnancy to postpartum (Chen, Chen, Kitamura, & Nemoto, 2016), and the impact of breastfeeding on postpartum resting HR (Groer, Jevitt, Sahebzamani, Beckstead, & Keefe, 2013).

Women in the current study did not experience any change in TC, HbA1c or glucose from baseline (visit 1) to post-intervention (visit 6). Holmes et al. (2018) reported no difference in measures of fasting glucose and HbA1c when comparing the effect of PAIGE with a control group, despite the intervention group experiencing significantly greater weight loss. Others (Hu et al., 2012; Wein, Beischer, Harris, & Permeze, 1999) have, however, reported improvements in glucose control following postpartum dietary interventions for women with previous GDM. The differences in results may relate to study size or inclusion of participants in the current study with both normal and impaired glucose regulation during pregnancy (*i.e.* inclusion of women with and without previous GDM). Lim et al. (2019) demonstrated that a postpartum weight gain of only 2kg led to greater increases in TG, and higher HbA1c, TC and LDL when compared to a weight loss and weight stable group, which highlights the importance of even a small amount of weight loss in improving cardiometabolic outcomes after pregnancy. Previous studies have shown that central adiposity is more common in women with PPWR, which likely contributes to the worsening of cardiometabolic risk (Gunderson et al., 2004). Given the great reductions in weight at follow-up, the current work contributes further evidence to the potential for the postpartum period to act as a window of opportunity to decrease obesity and chronic disease in later life (Rich-Edwards, Fraser, Lawlor, & Catov, 2014), although future work is required to determine the effects of this lifestyle intervention on cardiometabolic outcomes when the COVID-19 pandemic does not impact on the ability to collect girth measurements and blood samples.

5.4.4 Physical Activity

Results from the Fitbit data showed increases in total daily steps and active minutes in both the diet and exercise groups, and increases in total daily distance in the diet group only. There was, however, no change in calorie expenditure in either the diet or exercise group. Maturi et al. (2011) also demonstrated that a 12-week physical activity intervention was effective in encouraging significant increases in physical activity (65.6% vs. 32.5% engaging in vigorous physical activity after 12 weeks; $p<0.001$), but also demonstrated an increased energy expenditure per week (4394 vs. 1651kcal; $p<0.001$) between the intervention and control groups, which does not agree with the results of the current study. Gilmore et al. (2017) also utilised a Fitbit as part of a personalised 16-week mHealth intervention (E-Moms) whereby participants were encouraged to increase steps at a rate of 500 steps/day each week from baseline. Results showed no significant difference in weight change between the intervention and control group. The authors did not report on Fitbit outcomes, rather they used the number of days of recorded steps as a measure of study adherence. There was notable variability in study adherence which indicates that, whilst both the current study and the study by Gilmore et al. (2017) utilised a Fitbit to support intervention changes, the co-created intervention detailed herein with the input of postpartum women themselves demonstrated more positive outcomes (*i.e.* significant reduction in postpartum weight and increase in physical activity levels) and importantly, was accepted by women prior to implementation. Future work looking to improve postpartum physical activity levels and encourage weight loss management must therefore understand the views and opinions of the women themselves prior to the implementation of behaviour change programs.

5.4.5 Questionnaires

5.4.5.1 Short-Form 36

Results from the current study showed improvements across time in the physical functioning, energy/fatigue, pain and general health constructs in the diet group and improvements in physical functioning in the exercise group when analysing the SF-36 questionnaire. The increase in general health and energy in the diet group could be related to women's increased ability to control one's weight and lifestyle choices, as demonstrated by the greater weight loss experienced by the diet group compared to the exercise group. The Lifestyle for Effective Weight Loss during Lactation study aimed to evaluate the effect of a 12-week dietary intervention on weight loss among postpartum women living in Sweden and changes in QoL were also measured using the SF-36 questionnaire (Hagberg et al., 2019). Hagberg et al. (2019) also showed significant differences in general health in the dietary intervention group, and not the control group, at post-intervention. Differences in mental health were also observed by Hagberg et al. (2019), which does not agree with the current study where women did not display any changes in emotional wellbeing from pre- to post-intervention. It is plausible to suggest that the differences in eligibility criteria may explain these conflicting results, as, unlike Hagberg et al. (2019), women were excluded or withdrawn from the current study if they were diagnosed with postpartum depression or any other mental health issue that could influence weight. In other words, to participate in the current study, women were required to have good mental health, which may explain the lack of change from pre- to post-intervention. Previous research in non-pregnant obese populations has also shown that physical health, but not mental health, is improved following weight loss trials (Hayes, Baxter, Müller-Nordhorn, Hohls, & Muckelbauer, 2017), which agrees with the current work whereby both the diet and exercise groups experienced improvements in physical functioning throughout the study period. Further work should now look to understand any changes in physical health that occur following weight loss interventions in postpartum women with higher baseline BMI's, specifically those women with class I and class II obesity. This will allow for an understanding of the effect of weight loss interventions on SF-36 outcomes in women of all BMI status.

5.4.5.2 Godin-Shephard Leisure-Time Physical Activity Questionnaire

In the current study, women in both the diet and exercise groups showed improvements in LTPA scores throughout the intervention period. Albright, Maddock, and Nigg (2009) conducted a two-month pilot study aimed at improving moderate-vigorous leisure-time physical activity levels, measured using the Godin questionnaire, in postpartum multi-ethnic women. Results showed significant increases in physical activity levels at two months, which is in agreement with the current study. Other work has also shown significant pre- to post-intervention increases in moderate physical activity in a treatment group enrolled in the "Moms on the Move" program (Fahrenwald, Atwood, Walker, Johnson, & Berg, 2004). Future work should now look to examine the feasibility of the implementation of physical activity questionnaires (like the Godin-Shephard LTPA Questionnaire) into primary care settings, as this may create a gateway to discussion surrounding women's postpartum physical activity engagement.

5.4.5.3 Three Factor Eating Questionnaire

The 18-item revised TFEQ (TFEQ-18) was used to measure UE, CR and EE behaviours at each study visit. Women in both the diet and exercise groups experienced significant reductions in UE and percentage expression of UE, and increases in CR and percentage expression of CR, to similar degrees throughout the intervention and follow-up periods. There were also reductions in measures of EE throughout the intervention and follow-up period in the diet group only. Few previous studies have utilised the TFEQ-18 to examine eating behaviours during weight management interventions (Bryant, Rehman, Pepper, & Walters, 2019; Leon, Roemmich, & Casperson, 2019; Svensson et al., 2014), and none have been completed in overweight and obese postpartum women. One study demonstrated that, following an interactive web-based weight loss program at 6 months postpartum, individuals experienced similar decreases in UE to the current study (pre- to post-intervention; 56 to 32% vs. 56 to 36%) (Svensson et al., 2014). Individuals in the work by Svensson et al. (2014) demonstrated higher CR at baseline than in the current study (51% vs. 39%), however follow-up scores were identical (both 63%), indicating that women in the current study experienced greater improvements in self-control over food intake over the intervention and follow-up period. Regarding EE, women in the study by Svensson et al. (2014) showed less EE tendencies at baseline (~43% vs. 61%), but follow-up scores were similar (~43% vs. 39%), demonstrating that postpartum women appear to exhibit higher EE expression than women who have not had a baby in the previous 12 months. The results from the current study showed that the lifestyle intervention was successful in encouraging healthy improvements in postpartum eating behaviours, with additional improvements in EE behaviours when women are enrolled in a dietary intervention. Further work is now required, through the delivery of the TFEQ-18 to UK-wide postpartum women, to allow for the development of strategies to assist healthcare providers in targeting problematic eating behaviours (*e.g.* high levels of emotional eating) in new mothers.

5.4.5.4 Pittsburgh Sleep Quality Index

Results from the PSQI questionnaire showed improved sleep quality in the diet group only throughout the study period. This improved sleep quality may have played a role in the ability of women to make healthy dietary changes, especially as tiredness is often cited as a barrier to postpartum healthy eating (Chapter 3, current study; Albright et al., 2015; Cramp & Bray, 2010). Matenchuk & Davenport (2020) utilised the PSQI and assessed the influence of sleep quality on PPWR. Results demonstrated that meeting physical activity guidelines (≥150 minutes a week) and engaging in light activity were both associated with higher sleep quality and greater postpartum weight loss. These results do not agree with the results of the current study as women in the exercise group did not experience any change in PSQI throughout the intervention period, but experienced improvements in physical activity levels and postpartum weight loss. Exercise has, however, long been associated with better sleep quality (Youngstedt & Kline, 2006), therefore postpartum education should focus upon the importance of physical activity engagement to encourage both positive sleep and weight management outcomes.

5.4.6 Food Recalls

In the current study a multiple pass 24-hour dietary recall technique was administered using INTAKE24, which is considered the gold standard method for self-reported dietary intake (Østbye et al., 2009). Results showed a significant reduction in calories, fat, saturated fat, carbohydrate and protein intake throughout the study period in the diet group only. Huseinovic et al. (2016) included 24-hour food recalls and also showed a significant reduction in energy intake, fat intake and saturated fat intake following a 12-week postpartum dietary intervention, but showed an increased protein intake when compared to a control group. Østybe et al. (2009) showed non-significant changes in mean caloric intake and percentage of calories from fat at post-intervention in the Active Mothers Postpartum lifestyle program. However, women in the intervention group did not experience significant weight change in comparison to a control group, which does not agree with the findings from the current study or that of Huseinovic et al. (2016). Other dietary interventions delivered in the postpartum period have shown associations between a reduction in caloric intake from pre- to post-intervention and significant reductions in body weight (O'Toole, Sawicki, & Artal, 2003). The current findings highlight the importance of delivering appropriate dietary advice to postpartum women to encourage improvements in dietary intake and weight management, whilst recognising and addressing the challenges that women face during this time (*e.g.,* women in this thesis (Chapter 3) highlighted a lack of time as a barrier to healthy eating, so quick recipes were shared as part of the intervention detailed here).

5.4.7 Support

The current study utilised the WhatsApp mobile phone application as a means to support women, and to encourage women to support each other, in their postpartum weight loss journeys. Through the WhatsApp groups, women received behaviour change tips and advice, links to useful websites, recipe ideas, and were educated on the importance of a healthy postpartum lifestyle. There are mixed results regarding the use of mobile health (mHealth) technology for postpartum weight management (Gilmore et al., 2017; Sherifali et al., 2017). For example, Sherifali et al. (2017) showed that mHealth technologies were beneficial in supporting postpartum weight management, however Gilmore et al. (2017) showed that the delivery of real-time weight and physical activity monitoring, health information and feedback through the SmartLoss application (Martin et al., 2016) was not effective in eliciting significant weight change between intervention and control groups. Other weight loss interventions have not reported any significant effect of mHealth technologies on weight losses with up to 6-month interventions (Cavallo et al., 2016; Khokhar et al., 2014; Oh et al., 2015; Svetkey et al., 2015). It was recommended by Gilmore et al. (2017) that an understanding of practical barriers (*e.g.,* childcare and lack of motivation) should be sought prior to the delivery of mHealth approaches in postpartum women, which is specifically the work completed in this thesis and may be one of the reasons why the current study has demonstrated better success in encouraging postpartum weight loss compared to the work of Gilmore et al. (2017).

Withdrawal of support had an impact on the trajectory of weight loss in women enrolled in both diet and exercise interventions. Women in both groups experienced slight, but non-significant, weight loss between the post-intervention visit (visit 6) and the follow-up visit (visit 7). Huseinovic et al. (2016) delivered a 12-week dietary behaviour modification program to encourage postpartum weight loss in 54 overweight and obese women and showed a significant decrease in body weight in an intervention group when compared to a control group at both 12-weeks and 1-year follow-up. When comparing groups at 2-year follow-up there was no significant difference in weight, however a significant interaction was observed when women with a new pregnancy were excluded from analysis, highlighting that the intervention by Huseinovic et al. (2016) was effective in encouraging long-term weight management in postpartum women. Of note, women who gained weight between 1-year and 2-years reported a decrease in frequency of self-weighing compared to women who maintained or continued to lose weight, which highlights the importance of (i) including self-weighing strategies in the design of postpartum weight loss interventions and, (ii) encouraging women to continue to engage in such behaviours following intervention engagement to promote a healthy BMI throughout the childbearing years. Whilst the intervention employed by Huseinovic et al. (2016) appeared to elicit more positive effects at follow-up, women in the current study still experienced slight reductions in weight from post-intervention to follow-up. The follow-up period in the current study was short (4 weeks) and the majority of participants (*n*=14) were enrolled in the study during the COVID-19 pandemic. Future work should, therefore, look to utilise the intervention approach described in the current study and incorporate a longer follow-up period. This will allow for an assessment of the trajectory of weight loss in the months and years following intervention engagement and determine effects when UK-wide lockdowns are not in place.

5.4.8 Autonomy

This study is the first to provide women with the choice of engaging in either a diet or exercise intervention. Results showed that 17 women chose to engage in the diet pathway and 10 chose to engage with the exercise pathway. In line with the Self-Determination Theory proposed by

Deci & Ryan (1985), autonomous motivation has previously been associated with improvements in physical activity and healthy lifestyle behaviours (Hagger & Chatzisarantis, 2009; Knittle et al., 2018; Ng et al., 2012; Teixeira et al., 2012). There is also some evidence to suggest that weight loss may be greater in overweight and obese adults who are provided with autonomy support rather than directed support (Gorin, Powers, Koestner, Wing, & Raynor, 2014) although results in the area are inconclusive (Leavy, Clifton, & Keogh, 2018), and until now, the effect of autonomy on weight loss has yet to be investigated in postpartum women. Whilst women in the current study initially chose to engage in either the dietary or exercise intervention and received new information every 3 weeks to encourage steady but maintainable behaviour change, once the majority felt they were consuming a balanced diet or were engaging in ≥150 minutes per week of moderate-vigorous physical activity, they opted to focus on altering the other behaviour as well (diet or exercise). Women did not receive information leaflets related to the other intervention arm but were provided with advice, if requested. Whilst failing to provide advice would have ensured no crossover between intervention information, it was not seen as beneficial, as ultimately the intervention was delivered to encourage postpartum weight loss management and healthy lifestyle change. The sequential introduction of nutrition and exercise behaviours may allow a period of time to introduce one set of behaviour change strategies before adding the second (Hyman, Pavlik, Taylor, Goodrick, & Moye, 2007; James et al., 2016). Moreover, changing multiple behaviours (diet and exercise) at once is likely to tax self-control capacity and could result in self-regulatory failure (failure to monitor and alter one's thoughts and behaviours for a desired objective) (Baumeister & Vohs, 2007) more so than the sequential alteration of single behaviours (diet or exercise) (Baumeister & Juola Exline, 1999). Whilst work in pregnancy has shown that introducing exercise first followed by nutrition improves adherence to and outcomes from lifestyle modification programs (Nagpal et al., 2020), and other work in older adults and sedentary women has shown that exercise may be a gateway to dietary behaviour change (Dutton, Napolitano, Whiteley, & Marcus, 2008; Tucker & Reicks, 2002), this is yet to be formally determined in postpartum populations. Women in the current study sequentially introduced the other lifestyle behaviour (diet or exercise) at a time suitable to them, however future work should test the effects of sequential and simultaneous introduction of nutrition and exercise behaviours, to determine the efficacy of such approaches in encouraging adherence to, and outcomes from postpartum weight loss interventions.

5.4.9 Attrition

In the current study, the attrition rate was 26% at the end of the study, corresponding to seven withdrawals over the 20-week period. Of those seven withdrawals, five subsequently met the exclusion criteria once enrolled in the study. Two women were withdrawn because of reasons related to the COVID-19 pandemic (one was placed on antidepressants known to influence weight due to the death of a family member and one was advised by a medical professional to cease engagement in the study due to COVID-related symptoms). One woman was lost in the follow-up period due to pregnancy. The attrition rate observed in the current study is aligned with that from previous work in postpartum mothers enrolled in lifestyle interventions, although previous work has reported higher rates of chosen withdrawals. Nascimento et al. (2014) conducted a systematic review to study the effect of physical exercise strategies on postpartum weight loss (Nascimento et al., 2014). Five of the 11 included studies accurately reported dropout rates, with attrition ranging from 17% up to as high as 40% (Davenport et al., 2011; Leermakers et al., 1998; O'Toole et al., 2003; Østbye et al., 2009b; Walker et al., 2012). A more recent review aimed to summarise the evidence from RCTs to compare the effects of information and communication technology based interventions in supporting postpartum weight loss (Christiansen et al., 2019), and attrition rate in the eight included studies varied from 5.6% (Herring, Cruice, Bennett, Davey, & Foster, 2014) to 23.7% (Phelan et al., 2017). Financial rewards were suggested by Christiansen et al. (2019) to improve study adherence. Work by McGirr et al. (2020), with 100 postpartum women, piloted a 12-month text-message delivery service to support postpartum weight loss and provided monetary incentives to attend each data collection visit (£100 in total per participant throughout the study). Whilst McGirr et al. (2020) reported attrition rates of 14% in the intervention group and 9% in the control group, which is lower than in the current study and in much of the previous work on this topic (LeCheminant et al., 2014; Phelan et al., 2017), it is likely that many studies will not have the financial support to offer monetary incentives and the external validity of such approaches must be questioned. Furthermore, participants should be appropriately educated on the importance of healthy postpartum weight management, such that they volunteer for studies for the purpose of improving their health, and not because they are incentivised by monetary means.

5.5 Conclusion

The diet and exercise interventions delivered in the current study were effective in promoting postpartum weight loss, reductions in dietary energy intake and improvements in physical activity in overweight and obese postpartum women. Women in the diet and exercise groups experienced a 5.83 ± 3.41kg (7.54 ± 4.84%) and 3.98 ± 2.98kg (5.17 ± 3.76%) weight loss from baseline to follow-up. In the combined diet and exercise group, women experienced a 1.91 ± 1.23 $kg{\cdot}m^{-2}$ reduction in BMI at follow-up. With the knowledge that 75% of women are heavier at 1 year postpartum than pre-pregnancy, with 47.4% of women retaining over 4.5kg and 24.2% of women retaining over 9.0kg (Endres et al., 2015), the potential benefits of initiating a lifestyle treatment, such as the one described in this study, are substantial. Key aspects of the study design (*e.g.* mHealth technology support groups and the delivery of specific exercise advice through the form of leaflets) should be incorporated into routine postnatal care, to encourage postpartum weight loss in primiparous women and a healthy pre-pregnancy BMI in subsequent pregnancies.

Chapter 6: An Exploration into the Thoughts and Opinions of Postpartum Women Following Engagement in a Lifestyle Intervention: Exit Questionnaires

6.1 Introduction

In weight loss settings, exit interviews and questionnaires are useful to assess the overall experience of study participants, and to gather key information for the development of future interventions (Campbell-Voytal et al., 2017). Specifically, the exploration of participants' experiences allows us to further understand and contextualise the data obtained as part of the intervention, and the concurrent evaluation of factors leading to both withdrawal and engagement allows necessary adjustments to be made in the development of future interventions (Campbell-Voytal et al., 2017). Exit interviews have previously been used in various healthcare settings, including weight loss studies (Campbell-Voytal et al., 2017; Frie, Hartmann-Boyce, Jebb, & Aveyard, 2019; Lynch et al., 2017), indicating that such steps are good practice, especially as a means to increase the success of future interventions.

The intervention employed in Chapter 5 was underpinned by semi-structured interviews (Chapter 3) and PPI sessions (Chapter 4) during the design phase, and it was considered equally important to obtain feedback from the women that took part in the trial. Furthermore, given that the majority of the women who took part in the lifestyle intervention were enrolled when the UK went into lockdown as a result of the COVID-19 pandemic (16 of 27 women initially enrolled in the study) it was important to understand how the pandemic affected their commitment to and experience of the intervention. Recent work by Sport England has highlighted that for the first eight weeks of lockdown physical activity levels remained relatively similar to pre-lockdown, with a third of adults engaging in at least 30 minutes of moderate-vigorous activity on five or more days a week (Sport England, 2020). However, the social and economic impact of COVID-19 has undoubtedly affected some demographic groups more than others (*e.g.*, older adults, people from lower socio-economic groups and those with illness or disability) (Sport England, 2020). Furthermore, parents' lifestyles may be negatively impacted given the need to provide full-time childcare because of the closure of nurseries and schools and the inability to arrange childcare with individuals outside their own home, however this is currently unknown. Therefore, the aim of this study was to obtain feedback from postpartum women regarding their engagement in the lifestyle intervention described in Chapter 5 using an exit questionnaire. The study also aimed to understand what effect, the

COVID-19 pandemic had on women's commitment to and experience of the intervention, specifically on their physical activity levels and diet. Given the nature of the pandemic and associated lockdown restrictions, it was hypothesised that the COVID-19 pandemic would have a negative impact on participants' commitment to the lifestyle intervention and ability to meet their personal health-related goals.

6.2 Methodology

6.2.1 Design

In June and July 2020, participants who completed the lifestyle intervention described in Chapter 4 (*n*=20) were invited to complete an exit questionnaire specifically designed for this study and delivered using onlinesurveys.ac.uk. As all women had provided their mobile number at the start of the intervention, participants were sent an initial WhatsApp message to determine if they wished to complete the questionnaire or not. All participants indicated that they would be happy to complete the questionnaire, so were all sent individual links to the questionnaire. Participants were sent the link to the questionnaire at least two weeks following completion of the lifestyle intervention (range in time since study completion was 2-20 weeks). All participants were sent the same WhatsApp message informing them of the aims of the questionnaire:

Hi [name], hope you're well. Please find attached the link to the questionnaire. Please just let me know if you have any questions/encounter any issues when completing it and please provide as much information as you want- it'll be extremely useful in helping to inform future lifestyle intervention work with postpartum women. Just a reminder that your participant number in the study was [01-20] (you'll need this for one of the questions). Thank you very much.

The questionnaire (Appendix 6C) contained questions regarding women's satisfaction with their weight loss/results and various aspects of the design of the intervention; for example, women's thoughts about the WhatsApp group, text messages, Fitbit inclusion and the impact of being offered the choice of which intervention to be part of. Women were also asked to provide any further information regarding their answers and were invited to provide any suggested amendments or additions to future interventions.

6.2.2 Data Analysis

A descriptive approach was adopted to present the findings from the close-ended questions, with results split by group (diet or exercise). Open-ended questions were analysed using a modified thematic analysis (Braun & Clarke, 2006); the full process is described in section 3.1.2.7.

6.3 Results

The questionnaire was completed by 19 of the 20 women who were invited to take part. The non-completing participant, who was originally in the exercise group when enrolled in the intervention, was sent a follow-up WhatsApp message reminding her of the aims of the questionnaire and despite indicating that she would complete it, she did not complete the questionnaire in the required time frame.

6.3.1 Close-Ended Questions

Table 6.1 displays the results of the questions asked to all participants and table 6.2 displays the results from the questions asked to those individuals who were enrolled in the study during the COVID-19 pandemic. Results are also split into diet and exercise groups.

Table 6.1 Results of closed questions asked to all participants. Data are presented as percentage (no. of participants).

Question/Measure	**All participants (*n* = 19)**	**DIET group (n = 12)**	**EXERCISE group (n = 7)**
Level of satisfaction 1= not satisfied at all; 5= completely satisfied)			
1	0 (0)	0 (0)	0 (0)
2	0 (0)	0 (0)	0 (0)
3	47.4 (9)	50 (6)	42.9 (3)
4	10.5 (2)	8.3 (1)	14.3 (1)
5	42.1 (8)	41.7 (5)	42.9 (3)
Enjoy being part of WhatsApp group?			
Yes	89.5 (17)	83.3 (10)	100 (7)
No	5.3 (1)	8.3 (1)	0 (0)
Not sure	5.3 (1)	8.3 (1)	0 (0)
Influence of WhatsApp group on results			
Positively	78.9 (15)	66.7 (8)	100 (7)
Negatively	0 (0)	0 (0)	0 (0)
Neither positively nor negatively	21.1 (4)	33.3 (4)	0 (0)
Influence of texts on results			
Positively	52.6 (10)	50 (6)	57.1 (4)
Negatively	5.3 (1)	8.3 (1)	0 (0)
Neither positively nor negatively	42.1 (8)	41.7 (5)	42.9 (3)
Influence of Fitbit on results			
Positively	100 (19)	100 (12)	100 (7)
Negatively	0 (0)	0 (0)	0 (0)
Neither positively nor negatively	0 (0)	0 (0)	0 (0)
Sufficient time between visits?			
Yes	89.5 (17)	83.3 (10)	100 (7)
No- too long	10.5 (2)	16.7 (2)	0 (0)
No- too short	0 (0)	0 (0)	0 (0)
Not sure	0 (0)	0 (0)	0 (0)
Influence of choice on results			
Positively	89.5 (17)	91.7 (11)	85.7 (6)
Negatively	0 (0)	0 (0)	0 (0)
Neither positively nor negatively	10.5 (2)	8.3 (1)	14.3 (1)
Able to maintain commitment following support withdrawal?			
Yes	78.9 (15)	66.7 (8)	100 (7)
No	10.5 (2)	16.7 (2)	0 (0)
Not sure	10.5 (2)	16.7 (2)	0 (0)
Lifestyle change since study completion?			
Positively	84.2 (16)	83.3 (10)	85.7 (6)
Negatively	5.3 (1)	8.3 (1)	0 (0)

Stayed the same	10.5 (2)	8.3 (1)	14.3 (1)
Satisfaction with current lifestyle (1= not satisfied at all; 5= completely satisfied)			
1	0 (0)	0 (0)	0 (0)
2	5.3 (1)	8.3 (1)	0 (0)
3	26.3 (5)	33.3 (4)	14.3 (1)
4	47.4 (9)	41.7 (5)	57.1 (4)
5	21.1 (4)	16.7 (2)	28.6 (2)
Recommend to other mums?			
Yes	18 (94.7)	11 (91.7)	100 (7)
No	0 (0)	0 (0)	0 (0)
Not sure	5.3 (1)	8.3 (1)	0 (0)
Overall satisfaction as a participant			
Very satisfied	63.2 (12)	50 (6)	85.7 (6)
Mostly satisfied	36.8 (7)	50 (6)	14.3 (1)
Neither satisfied nor dissatisfied	0 (0)	0 (0)	0 (0)
Mostly dissatisfied	0 (0)	0 (0)	0 (0)
Very dissatisfied	0 (0)	0 (0)	0 (0)

Table 6.2 Results of closed questions asked to all participants who were enrolled in the study during the COVID-19 pandemic. Data are presented as percentage (no. of participants).

Question/Measure	**All participants (n = 14)**	**DIET group (n = 8)**	**EXERCISE group (n = 6)**
How has the pandemic affected results in the study?			
Positively	14.3 (2)	0 (0)	33.3 (2)
Negatively	35.7 (5)	50 (4)	16.7 (1)
Neither positively nor negatively	50 (7)	50 (4)	50 (3)
How has the pandemic affected diet?			
Positively	35.7 (5)	12.5 (1)	66.7 (4)
Negatively	35.7 (5)	50 (4)	16.7 (1)
Neither positively nor negatively	28.6 (4)	37.5 (3)	16.7 (1)
How has the pandemic affected physical activity levels?			
Increased	42.9 (6)	50 (4)	33.3 (2)
Decreased	14.3 (2)	25 (2)	0 (0)
No change	42.9 (6)	25 (2)	66.7 (4)
How has the pandemic affected commitment to personal goals?			
Positively	35.7 (5)	25 (2)	50 (3)
Negatively	35.7 (5)	50 (4)	16.7 (1)
Neither positively nor negatively	28.6 (4)	25 (2)	33.3 (2)

6.3.2 Open-Ended Questions

Seventeen of the 19 participants provided additional information in the text boxes provided on the questionnaire. The codes have been grouped into different themes; specifically, 'Overall satisfaction', 'WhatsApp group/text message support', 'Timing of enrolment/study visits', 'Frequency of weigh ins', 'Continued commitment' and 'Suggested improvements.' Additionally, themes regarding the COVID-19 pandemic are 'Changes in eating behaviours', 'Boredom eating/eating in response to stress' and 'Routine and restrictions.'

6.3.2.1 Overall satisfaction

Participants described high levels of satisfaction and enjoyment regarding involvement in the intervention. Participant 14 stated that she "really enjoyed being part of the study", which was similar to the thoughts of participant 23 who said, "Steph was great, lovely person and I enjoyed being part of the study." Two participants from the exercise group also highlighted satisfaction with the study, particularly as it helped them to get fitter. One woman said, "The study was amazing and helped me lose my baby weight. I am also the fittest I have ever been. I feel great!" (Participant 26) and another said, "Research participation was a very positive experience, it definitely helped me to focus more on getting fitter (probably my primary goal) and losing weight (plus dropping centimetres off my waistline)" (Participant 27).

6.3.2.2 WhatsApp group/text message support

Many participants offered insights into their opinions of the WhatsApp group and text messages as a means of support throughout the intervention. Women described the WhatsApp group as a motivational tool, especially as a platform for hearing when other women were exercising and for sharing recipe ideas. For example, one women said, "The WhatsApp group was very motivational and it was good to hear tips from other people on the study and when they said they had done some exercise it motivated me to go and do something" (Participant 12), and another mentioned that "the WhatsApp group was really helpful for motivation, and being held accountable" (Participant 24). Similarly, two other participants echoed similar thoughts by saying that the "WhatsApp group was a great resource for recipes and seeing how everyone was getting on" (Participant 2) and, "I found being in contact with other mums in the study helpful and reassuring. It was great to share recipes and experiences" (Participant 14).

Participant 1 offered more negative thoughts on the WhatsApp group and text messages as she said, "I found the texts quite patronising- probably more unnecessary than negative. And the WhatsApp group was just a bit annoying. Recipes were useful but I could take or leave the chat." She also described how the decision to make a lifestyle change had to come from her and the additional support aspects, in her opinion, were not needed. She mentioned, "I suppose I had to make a decision to help myself really. It was useful having to be weighed every 3 weeks and to answer to that but just didn't need the other bits" (Participant 1).

6.3.3.3 Timing of enrolment/study visits

Women described that enrolling in the study closer to the birth of their baby was more beneficial as it prevented the development of unhealthy habits. For example, participant 12 described:

> "I started the study not long after my 6-week check and I think this was positive as it stopped me getting into bad/lazy habits early on. Many of my friends that had babies at a similar time put on a lot of weight in the few months after having a baby and I think this study stopped me doing this as I was motivated to try to get back to being fit and healthy."

One woman said that she wished she had started the study earlier as she had developed bad habits by six months postpartum. She mentioned:

> "I also wish I had started the study closer to the birth of my daughter. She was nearly 6 months when I started and I had got into a lot of unhealthy habits that I had to break. I think when she was about 3 months would have been an ideal time to start." (Participant 21)

Participants also described that being on maternity leave at study enrolment made it easier to make changes, but returning to work during the final four unsupported weeks was difficult. Participant 12 stated, "If I'd started the study once I was back at work I think it would have been more difficult" whilst participant 25 mentioned that:

> "Timings of the study coming to an end were unfortunate for me, my last weigh in before being left to my own devices for 4 weeks was the day before I was due to start back at work (working from home). I struggled to introduce exercise and keep on track eating wise in those first 4 weeks as I was settling into my new routine."

6.3.3.4 Frequency of weigh in's

Participants expressed satisfaction with the frequency of weigh in's as it kept them on track but also allowed them the time to make any adjustments between visits. Participant 9 mentioned that, "Regular weigh ins were helpful to know how my progress was going" and participant 25 said, "The 3-weekly weigh ins also gave me something to aim for." Moreover, one woman described, "I think 3 weeks per weigh in was a great time because if you have a bad day/week or have certain events you can balance that out the other weeks" (Participant 2).

6.3.3.5 Continued commitment

Many participants described their ability to continue engaging in a healthy lifestyle following the conclusion of the study and the importance of setting a good example for their child. Participant 2 mentioned that she still "keeps all the info in the back of my mind" and that she is "well set up to lose weight in the future if needed" whilst another participant highlighted her continued weight loss, "with the insight from the study I went on to use the diet materials alongside exercise during the pandemic and have managed to lose another stone in weight. I am really pleased" (Participant 10). Participant 16 also described similar thoughts as she said, "the study has helped me maintain the exercise, healthy life balance I wanted to achieve at the beginning. I am happy to say that I have incorporated the plan into my everyday life." Participant 27 told that "participation in the research was just the start of the transition to become an active parent, now the journey continues. I definitely want to set a good and healthy example for my daughter." One woman also explained how her sustained reduced BMI from the study enabled her to be eligible for a home birth with her second pregnancy as she said, "My BMI was low enough at my first appointment that I was put down as low risk of gestational diabetes and can have a home birth- that was definitely thanks to the study" (Participant 1).

Some participants described difficulties with following a healthy lifestyle; injury and the COVID-19 pandemic had a negative impact on everyday life. Saying this, women highlighted that they were aware of the necessary adaptations needed to continue with weight loss. Participant 21 described the impact of a back injury on exercise participation as she said:

> "Unfortunately I have not been able to do much in the way of exercise in the last two weeks as I have injured my back however I have tried to be extra careful with my diet

> so I don't regain what I've lost. I am about 5lbs away from my pre pregnancy weight and I am motivated to get there especially once I am able to exercise again."

Participant 25 mentioned her struggles at incorporating the changes made during the study into her lifestyle following the easing of lockdown restrictions. She said,

> "I feel that I am struggling to introduce my learnings through the study into 'normal life' as for the majority of the study life has been very abnormal which I do feel is a shame as by now I may have been in a bit of a routine with a healthier lifestyle."

However, even though the changes were slower than she would have liked she stated that she hopes "to continue to lose some more weight and continue to reduce [her] BMI" (Participant 25).

6.3.3.6 Suggested improvements

Nine participants offered suggestions regarding amendments and additions to the study if it were to be completed again in the future. Women suggested adaptations to the WhatsApp group as one mentioned:

> "One thing that I think would have made me stay on track a lot more was to have to put on the WhatsApp group what I had eaten for breakfast, lunch and dinner every day. Doing this would not only keep me on track but it also gives ideas of what to eat to other participants." (Participant 15)

Another woman described that she has been unable to find another platform to discuss exercise with other new mums and wished the groups could continue. She said:

> "It would be good if the WhatsApp group could continue for those that were willing as it was nice to meet like-minded health and fitness conscious people. A lot of the baby groups I have been to, people haven't been interested when I have spoken about exercise." (Participant 12)

Participants also offered ideas regarding adaptations to the study once women had returned to work following maternity leave. Participant 22 highlighted that "it might be useful to consider lunches for working mums as it was definitely a challenge to maintain the same commitment to weight loss after returning to work" whilst participant 21 described that the WhatsApp group, in particular, was hard to follow after returning to work and suggested a buddy system instead. She said:

> "When I was on maternity leave I found the programme easy to follow and the WhatsApp group very helpful. Once I returned to work I found three weeks between visits too long as I was struggling to stay motivated and found the WhatsApp group quite overwhelming as I wasn't able to check the messages as they were coming

> through and would often have too many messages to be helpful by the end of the day. For the mums that have returned to work I feel more of a buddy system where you have only one or two people as a support group would be easier to manage and therefore you would get more from it."

Other suggested amendments and additions included the sequential introduction of exercise and diet, including the opportunity to meet other participants and the creation of a bank of recipes for women to access throughout the study. One woman described how she wished she could have received the diet materials as part of the study, rather than at the end as she said, "Although I wasn't doing the diet side of the study and I think it's good to focus on one area first, actually I think I would have really benefitted from receiving the diet materials about the half way point" (Participant 10). Another woman mentioned that meeting other participants would be a valuable addition as she mentioned, "Meeting other participants- it would have been more beneficial for participants to meet once they have joined the program (appreciate that taking part was staggered and most people have started at different times)" (Participant 27). Participant 14 explained that a bank of recipes would be especially useful for those who lack confidence in the kitchen as she said,

> "My only suggested improvement would be that it would be great to have a library of low-fat recipes for participants to go in and use. Whether this is in a booklet form or something online, I think it would be useful. Especially for those who aren't as confident in the kitchen."

One woman expressed a desire for more specific dietary targets as she mentioned, "looking at the advice in the exercise leaflets after finishing it seemed a lot more tangible than the nutrition, I think I would have benefitted from more specific targets asides from reducing calorie intake" (Participant 22), and another wished that the "weigh in's be closer in time" (Participant 17). Although not specifically related to the study, participant 27 also offered her opinion on changes to areas of postpartum care as she said, "A suggestion that perhaps the health visitors could do more in this area (consequences for the subsequent pregnancies, impact on children and families)."

6.3.4 Questions related to the COVID-19 pandemic

6.3.4.1 Changes in eating behaviours

As a result of the COVID-19 pandemic participants described changes to eating behaviours. Some participants described having more time to prepare nutritious food, but others cited having to balance childcare and work as a barrier to meal preparation. Women also described that snacks and treats were prepared and eaten a lot more often than before lockdown restrictions were implemented. Participant 12 explained:

> "As we are no longer going out or having takeaways, we are cooking meals from scratch most days due to having more time so we are generally eating healthier. However, I am baking more so we do have a lot of treats in the house but I am trying to restrict myself to one a day and only if I've exercised."

Participant 25 also echoed the opinions of Participant 12 by saying:

> "Not being able to go out and socialise and have more time to cook did make it easier to eat healthier when ingredients were available however being stuck at home did make it easier to snack and for treats saved for special occasions to be readily available (Easter didn't help the situation)."

However, Participant 22 struggled to find the time and motivation to dedicate to food planning, especially at the weekend as she mentioned, "Trying to balance work and childcare meant didn't have same amount of time/headspace to give to meal prep and planning…Ate out less but definitely more tempted to binge at home at weekends as no other social outlet."

6.3.4.2 Eating in response to boredom and stress

Many women described eating due to boredom and stress, particularly at the start of lockdown when restrictions were the strictest. Participant 15 highlighted how, following the easing of restrictions, she found it easier to diet and increase activity. She said:

> "At the start of the pandemic I was surrounded by food as I was at home all the time and boredom got me eating too much. As lockdown was relaxed I could walk a lot more and I then felt dieting easier than before the pandemic hit. It was the initial time March/April where I struggled most."

Similarly, participant 16 explained how the pandemic affected her motivation which resulted in comfort eating, "Before the pandemic I had a routine and plan. During the lockdown I felt lost, unmotivated, angry, and stressed. This resulted in comfort eating and lacking motivation at times." One woman described how both returning to work prior to lockdown and then working from home had a negative impact on her eating behaviours. She highlighted the importance of support from her partner in helping to increase exercise levels during the pandemic as she said:

> "Before the pandemic I had just returned to work and found I was struggling to stay motivated. I think this was linked to reduced sleep as my daughter went through a period of very frequent night waking and not settling again for between 20 mins to an hour. I often felt the need to eat due to tiredness rather than hunger. I was in a similar

situation when working from home and I found stress became very definitely a trigger to snack as I found it hard to balance working from home and looking after a 9 month old as my partner had to work through the majority of the pandemic. During the three weeks my partner had off during the pandemic my motivation increased as did my exercise as I was running 3 times a week and completing an exercise DVD on 2 other days however since he has returned to work the opportunity to exercise decreased and I went to walking every day and running 2 days a week. My diet distinctly improves when my partner was off and I was snacking much less. I have managed to maintain this to a large extent and only have planned healthy snacks rather than impulse snacking." (Participant 21)

Participant 25 also identified that if she had not been involved in the study it is likely she would have gained weight, especially due to emotional eating as she said:

> "I do believe if I hadn't been involved in the study during lockdown I would have put on weight as I probably wouldn't have considered what I was eating and potentially could have emotionally eaten through times of worry and stress."

6.3.4.3 Routine and restrictions

Women described a change in routine following the implementation of lockdown because of the COVID-19 pandemic. In most instances women described negative changes to routine, however many women highlighted an increased motivation to exercise and the ability to focus more on a healthy lifestyle if they had returned to work prior to lockdown. Participant 22 described, "Only being allowed out once a day reduced exercise drastically as time outside in that outing was limited by how long baby would spend in buggy" whilst participant 17 said, "Being stuck home more is harder and routine is harder. But I'm walking 12k a day." Participant 19 found it easier to follow a healthy lifestyle during this time as she was working less. She explained:

> "I had returned to work when lockdown happened, I went from being full time to working 3 days in every 2 weeks. This enabled me to really focus on my diet and exercise and build in a routine. I am now finding it harder as I am back working full time and my baby's sleep has regressed. I am therefore finding it more difficult to have a set routine."

Participants 12 and 27 did not believe that the pandemic had a negative impact on their routines, especially as they were on maternity leave prior to the pandemic and had the motivation to continue to make healthy dietary choices. Participant 12 described an agreement between her and her husband regarding exercise as she stated, "As I was on maternity leave before the pandemic, my daily routine hasn't been greatly affected so we are still walking lots and my husband and I take it in turns to do exercise at lunchtimes" and participant 27 mentioned:

> "Being restricted to having days out was the biggest challenge, this resulted in staying at home a lot more- having more access to food between mealtimes (although I was trying to make healthy choices!). But in general, I don't think I was negatively impacted."

Participant 25 also described the impact that the weather had on her exercise levels during the pandemic as she said:

> "My physical exercise both increased and decreased during the pandemic, as we were only allowed out for 1 hour a day and we had such wonderful weather early on in lockdown my exercise increased as we went on plenty of walks to just get out of the house. I also enjoyed doing workouts shared by Steph in my garden in the nice weather. However on the days when the weather wasn't so kind my exercise levels dropped significantly to hardly any steps a day. There were a few weeks where we barely left the house due to the weather. If there hasn't been a pandemic happening I believe I would have had higher exercise levels from being allowed out."

6.4 Discussion

This study aimed to obtain feedback from postpartum women regarding their engagement in a lifestyle intervention (Chapter 5) and to understand what effect the COVID-19 pandemic had on their results.

Results showed that 52.6% of individuals believed that the text/short message service (SMS) had a positive influence on their study outcomes, whilst 42.1% of women believed that the messages did not negatively or positively impact their results. Recently, McGirr et al. (2020) developed a SMS intervention to support behaviour change for weight loss and weight loss management in overweight and obese postpartum women and, like the current work, assessed the acceptability of the SMS messages. PPI sessions were incorporated into the design of the intervention whereby women were asked to comment on the clarity, tone and length of the messages to be sent in the first 12 weeks of the 12-month intervention. Text messages included links to useful resources and the opportunity to reply 'yes' or 'no' in response to behaviour change and maintenance prompts (e.g. "Have you set your activity goal for the week ahead?"). Eighty to 90% of participants were 'very satisfied' or 'mostly satisfied' with the SMS messages at all study visits which is substantially higher than the 52.6% of participants in the current study who believed that the text messages had a positive influence on their overall results. However, the text messages in the current study did not include any links to online resources and were motivational (*e.g.*, "It's a lifestyle change. It won't happen straight away, keep working at it.”) or reminded participants of tips to encourage behaviour change (*e.g.*, “Go to the supermarket with a list and stick to it. Don’t be tempted by the unhealthy food deals.”). Unlike the work by McGirr et al. (2020), the text messages in the current study were not the central element of the intervention. Nevertheless, future work should look to both refine the language and tone of text messages as evidence indicates that the portrayal of messages can influence behaviour change (Cole-Lewis & Kershaw, 2010), especially as postpartum lifestyle interventions with supporting technology have shown great promise in encouraging significant weight loss (Christiansen et al., 2019). Furthermore, despite including both SMS messages and the option for telephone calls as part of the current lifestyle intervention none of the participants indicated that they wished to arrange a call at any point throughout the intervention. In future, the acceptability of telephone calls as a means of supporting postpartum women in weight loss interventions should also be assessed given the reduced participant time commitment of such approaches, which may be especially appropriate for postpartum women as they have previously cited a lack of time as a barrier to engagement in lifestyle interventions (Carter-Edwards et al., 2009).

Results showed that 78.9% of women believed that the WhatsApp group had a positive influence on study outcomes, whilst 21.1% said the group did not have a positive or negative impact on results. The majority of women also enjoyed being part of the WhatsApp group (89.5%). The rise of mobile applications is an important development in health and healthcare, particularly social applications (*e.g.*, WhatsApp and Facebook) that provide a platform for peer-to-peer support and health education (Kamel Boulos et al., 2011; Kamel Boulos et al., 2014). In healthcare, the use of WhatsApp and Facebook groups have proven effective in preventing smoking relapse (Cheung et al., 2019), improving service delivery in areas of public health (J. V. Henry et al., 2016), and enabling the delivery of information and support for pregnant women outside of antenatal visits (Patel et al., 2018). Recently, a systematic review exploring postpartum women’s perspectives of digital health interventions for lifestyle management has revealed high acceptability of such interventions (Siew Lim, Tan, Madden, & Hill, 2019). However, women cited barriers to engagement in digital lifestyle interventions, for example, childcare responsibilities and a lack of time. Lim et al. (2019) recommended that the development of future digital health interventions should complete an initial assessment of the lifestyle barriers faced by postpartum women; a step taken in the current body of work (described in Chapter 3). In overweight and obese postpartum women, the acceptability and feasibility of a 12-week Facebook-delivered weight loss intervention has been investigated (Waring et al., 2018). Engagement was sustained throughout the intervention as 100% of women posted on the Facebook group, or engaged with an existing post ('liked' or commented) in the final 4 weeks, 63% did so in the last week and 42% did so on the last day of the intervention. Eighty-eight percent of women said they would be 'very likely' (41%) or 'likely' (47%) to participate in the intervention again if they had another baby, and 82% would be 'very likely' (29%) or 'likely' (53%) to recommend the program to a friend. These results are very similar to the current work whereby almost 80% of women viewed the WhatsApp group as having a positive impact throughout the intervention period. Both the current study and the work by Waring et al. (2018) have demonstrated that a lifestyle intervention delivered through a social network is highly accepted by overweight and obese postpartum women.

In the current study, 100% of postpartum women believed that their results were positively impacted due to having use of a Fitbit for the duration of the intervention. Research has shown that activity trackers are well accepted by various populations, including adolescents (Ridgers et al., 2018), older adults (McMahon et al., 2016; Valenzuela, Okubo, Woodbury, Lord, & Delbaere, 2018), and chronic disease and cancer populations (Mercer et al., 2016; Nguyen et al., 2017; Rossi et al., 2018). Previously, Choo et al. (2016) assessed the acceptability and usability of a mobile application linked with an accelerometer as a supportive tool for a clinic-based weight loss. Results showed that overall satisfaction with the app and accelerometer was only around 50% and individuals did not achieve significant weight loss over the one-month study period. In future, an understanding from participants of what aspects of the app and accelerometer require modification should enable the development of more accepted and successful interventions. It does not appear that any work has been completed to assess the acceptability of accelerometers in postpartum women enrolled in weight loss trials however, adherence to wrist-worn accelerometery is high as at 2-3 weeks and 5-6 weeks postpartum 82.6% (166 of 201 eligible) and 70.1% (141 of 201 eligible) of women wore an accelerometer for at least 7 days (Wolpern et al., 2019). All women in the current study believed that the Fitbit had a positive influence on their results and several also purchased their own activity tracker following completion of the intervention, which demonstrates high acceptability. Future work should look to assess the acceptability and usability of accelerometers in a larger sample of overweight and obese postpartum women combined with other strategies, for example technology-based group support, and completed over a longer period.

Results from the current study showed that 89.5% of women thought that being offered the choice of being part of either the exercise or diet intervention had a positive influence on their results. Self-Determination Theory proposes numerous motivational sub-categories that can be placed along a continuum ranging from controlled motives to autonomous motives. Autonomous motivation is characterised by a feeling of choice, freedom from external pressure to engage in a specific behaviour and volition (Knittle et al., 2018). Associations between autonomous motivation and improvements in physical activity and other healthy lifestyle behaviours are present in the literature (Hagger & Chatzisarantis, 2009; Teixeira et al., 2012), as well as evidence of long-term physical activity maintenance (Knittle, De Gucht, Hurkmans, Vlieland, & Maes, 2016; Ng et al., 2012). Despite this, the effect of autonomy on behaviour change and weight management is yet to be investigated in overweight and obese pregnant and postpartum women. A 2018 systematic review and meta-analysis aimed to explore if a choice of weight loss strategy results in greater weight loss in male and female adults (Leavy et al., 2018). The authors concluded that, from the nine studies included in the review, offering overweight and obese individuals with a choice of dietary treatment rather than prescribing a specific regimen does not influence weight loss. In other areas of healthcare, an element of choice has been included in the study design of, for example, drug therapy treatments (Bakker, Spinhoven, van Balkom, Vleugel, & van Dyck, 2000; Schumacher et al., 1994) and clinical interventions (Cooper, Grant, & Garratt, 1997; Rovers et al., 2001). However, the influence of patient and participant preference on predetermined outcomes is still relatively unknown in various populations. Clark and colleagues (2008) investigated the effect of choice of intervention type on physical and psychosocial functioning in older women with heart disease (Clark et al., 2008). The study involved a two-step randomisation process whereby women were randomised to a ‘choice’ or ‘no choice’ study arm followed by further randomisation of the ‘no choice’ arm to self-directed, group intervention or control group. Women who were randomised to the ‘choice’ group could choose to be part of the self-directed or group formats. Results showed that physical and psychosocial functioning was enhanced up to one year in women who were offered the choice and women who elected to be part of the group format. Although women indicated a preference to be part of a group, cardiac symptom control was better achieved in the self-directed format at 18 months. Clark et al. (2008) concluded that intrinsic (*e.g.,* sense of control) or external factors (*e.g.,* motivation effects) may explain these findings, although further work was required to fully understand potential explanations. The current study is the first in postpartum women to include an element of choice in the intervention design. Women achieved extremely positive results (see Chapter 5); specifically, substantial reductions in BMI and improvements in body composition and physical activity levels. Further work, akin to the conclusions made by Clark and colleagues (2008), is, however, required to gain a more comprehensive understanding of how autonomy affects lifestyle intervention outcomes in postpartum women and if behaviour change and weight loss management can then be sustained in the long-term.

Results from the current study demonstrated that the COVID-19 pandemic had differing effects on lifestyle, specifically diet and physical activity levels, of postpartum women enrolled in a weight loss intervention at the onset of lockdown restrictions. Whilst it was not possible to identify any UK based studies, in Italy a survey study was completed by 3,533 respondents aged 12-86 years, which aimed to investigate the effect of the COVID-19 pandemic on lifestyle changes and eating habits (Di Renzo et al., 2020). BMI in the study group was 27.66 ± 4.10 $kg{\cdot}m^2$ and female respondents represented 76.1% of the population. Similar to the results in the current study, whereby 50% of women believed that the pandemic neither positively nor negatively impacted their results, 46.1% of the Italian respondents believed that lockdown did not change their lifestyle habits. Whilst it may be expected that physical activity levels would reduce during lockdown due to restrictions on outdoor exercise and closures of gyms and exercise spaces, individuals in both the Italian survey and the current study reported increased or sustained exercise levels. In Italy, when compared to pre-pandemic times, a higher frequency of training was found during the pandemic ($p<0.001$) and women in the current study reported that physical activity levels had either increased (42.9%) or been maintained (42.9%) during lockdown. In the current study, whereas a combination of walking/running and circuit style exercises was recommended pre-pandemic, following the implementation of lockdown measures women were sent pre-recorded exercises and suggested 20-30 minute sessions at least three times a week that could be completed with minimal equipment in the home or garden. Similarly, 37.4% and 35.8% of the Italian study population reported eating more or less healthy food (fruits, vegetables, legumes and nuts), respectively which is similar to 35.7% and 35.7% of women in the current study who reported that the pandemic had a positive or negative impact on their diet, respectively. Results demonstrated that the majority of women described that their routines were negatively impacted following the implementation of lockdown, and often a loss of routine and motivation resulted in comfort eating which likely resulted in poorer intervention outcomes. Restrictions on daily exercise outside the home also likely had a negative influence on intervention outcomes. During the first lockdown (March 2020-end of study), continued or even heightened support was provided to women enrolled in the lifestyle intervention to encourage the maintenance or further improvement of lifestyle changes during this time. As such, drawing direct comparisons with studies similar to the Italian survey study is difficult as the general population were asked only to report on any changes to lifestyle during the pandemic and were not provided with any lifestyle support. In the current study, during the pandemic, scales and study packs were left on women's doorsteps and often, zero face-to-face interaction occurred. Therefore, the WhatsApp groups were utilised a lot more during this time to motivate women to maintain or continue to work towards a healthy lifestyle. Concurrently, women reported that being part of the intervention, and the associated support, encouraged weight loss maintenance and healthier lifestyle choices than if they were not enrolled in the study at the onset of lockdown restrictions. Furthermore, women who had returned to work pre-lockdown described having more time to focus on a healthy lifestyle as they were at home a lot more. This finding offers agreement with suggestions made by Atkinson et al. (2020) that the move towards working from home may afford postpartum women greater flexibility in their daily routine to incorporate physical activity. Nevertheless, it is evident that the COVID-19 pandemic affects individuals' lifestyles differently and support, for example from family members, during this time is crucial to encourage healthy lifestyles.

6.4.1 Reflections

It is worthwhile acknowledging that I was extremely passionate and enthusiastic about helping to support all women enrolled in the study which is likely to have had a positive impact on their experiences as participants. I took great pride out of the fact that I was playing a part in improving these women's lifestyles and provided them with the upmost support to help them achieve their weight loss and behaviour change goals. Following engagement in the intervention, one woman described being offered a home birth for the delivery of her second baby which was not possible for her first because of her elevated BMI and another entered a half marathon not long after finishing the study, which she said would not have been possible prior to enrolling into the study. Hearing stories like this and knowing that I played a part in these events has only heightened my passion to continue to support women in their weight loss journeys following pregnancy. I would now love to be able to deliver the intervention as a larger multi-centre trial to encourage increased external validity (Bellomo, Warrillow, & Reade, 2009).

6.5 Conclusion

The findings from Chapter 5 demonstrate that the lifestyle intervention was effective in inducing positive health outcomes (*e.g.*, 6.4% reduction in body weight) from pre- to post-intervention. The current study highlights that, as well as being successful from a physiological perspective, all women were 'highly satisfied' or 'mostly satisfied' as a participant in the study and 18 of 19 women would recommend the study to other mums.

The exit questionnaire has enabled a greater understanding of the findings in Chapter 5, especially regarding the effect of a global pandemic. The COVID-19 pandemic has undoubtedly created unprecedented challenges for individuals and society. The delivery of this exit questionnaire has enabled us to gain a novel, subjective insight into how a global pandemic, and its associated restrictions on individuals' lifestyles, affects postpartum mothers from a weight management and health perspective. Whilst 50% of women believed that the COVID-19 pandemic did not affect their results in the intervention, more than a third (35.7%) believed that it had a negative impact on their results. Therefore, whilst the intervention produced extremely desirable outcomes (*e.g.*, clinically significant weight loss, increases in physical activity levels and improvements in dietary behaviours) it would be plausible to suggest that it could have encouraged even greater weight loss if not delivered during a global pandemic, especially as 14 of 20 women who completed the intervention during the lockdown.

Findings showed that future work should determine the optimal content and tone of text messages when embedded into behaviour change interventions. Specifically, future work should pilot various text message approaches (*e.g.*, information based and/or motivational based) with postpartum women to determine their views and opinions on such approaches prior to incorporation into behaviour change programs. As technology is now commonly used as a means to deliver healthcare advice, it is possible that, following pilot work, a text messaging service incorporated into routine postnatal care, could aid in encouraging postpartum weight loss management and a healthy lifestyle with minimal additional time commitment from primary healthcare providers. The innovative inclusion of an exit questionnaire and associated feedback from postpartum women has now ignited ideas, and acted as further formative work, for the development and delivery of future lifestyle interventions in the population.

Chapter 7: General Discussion

7.1 Key Findings

The studies within this thesis have assessed the perceived barriers to healthy eating and exercise during and following pregnancy, with the aim of co-creating a lifestyle intervention with postpartum women to minimise these perceived barriers and encourage weight management and health in overweight and obese women following childbirth. The main findings of this thesis are summarised below:

1. Overweight and obese women identified an array of barriers when attempting to eat healthily and exercise during pregnancy and in the postpartum period. During pregnancy, tiredness, lack of support (little advice and discouraged engagement) and physical constraints (bigger and more cumbersome, nausea, need toilet more often) were cited as barriers to exercise engagement. Perceived barriers to healthy eating during this time included cravings, nausea, and a lack of restraint. In the postpartum period, medical complications, and a lack of convenience and routine prevented exercise engagement. A lack of time and routine, and tiredness prevented healthy eating in the postpartum period [Study 1, Chapter 3].
2. Postpartum exercise interventions should be individualised. Specifically, exercise programmes need to be designed such that women can participate without having to arrange childcare and are able to exercise at any time of the day. The prescribed exercise should be a combination of strength and aerobic-based type exercises and the intensity of the program needs to increase gradually whilst being individualised to each woman [Study 2, Chapter 4].
3. Postpartum dietary interventions should include quick recipe ideas and provide nutritional advice. A mobile phone application, rather than weighing food or completing a written food diary, should be used to track nutritional intake [Study 2, Chapter 4].
4. A postpartum lifestyle intervention should include weigh-in's at various points throughout the intervention and should offer the choice of engaging in either an exercise or dietary intervention. Support should be included as part of the intervention, through text messages and phone calls, and group-based forums [Study 2, Chapter 4].
5. Formative work, understanding postpartum women's barriers to a healthy lifestyle and developing strategies to mitigate these perceived barriers is an essential step in the design and delivery of postpartum lifestyle interventions.

6. A co-designed lifestyle intervention was effective in encouraging reductions in BMI, and improvements in dietary intake and physical activity levels in overweight and obese postpartum women [Study 3, Chapter 5].
7. Women engaging in a lifestyle intervention experienced improvements in measures of body composition (increase in FFM and FMI), using DXA scans [Study 3, Chapter 5].
8. Following engagement in a co-designed lifestyle intervention, women were satisfied as participants in the study and would recommend the study to other mothers [Study 4, Chapter 6]. A third of the women who completed the intervention believed that the COVID-19 pandemic and associated lockdown restrictions had a negative impact on their results [Study 4, Chapter 6].

7.2 Impact and reach

This thesis (the work itself and its findings) has demonstrated substantial impact (see Figure 7.1) in a variety of ways: (i) it has given overweight and obese women a voice in the scientific community, allowing them direct input into the design and implementation of a lifestyle intervention; (ii) it has resulted in immediate impact for those women in the lifestyle study who lost weight and/or saw improvements in several indices of health; (iii) it has the potential to impact the offspring of those women who undertook the lifestyle intervention; (iv) its findings are generalisable given the sample size.

Following the involvement of postpartum women in the co-design of a lifestyle intervention, overweight and obese women experience considerable reductions in postpartum BMI and improvements in health, and are highly satisfied with the approaches taken to elicit these improvements. Findings from the exit questionnaire delivered in Chapter 6 demonstrates that all women were satisfied as participants in the study and would recommend the study to other mothers.

Findings from the intervention show that, of the women that attended follow-up, six women were classified as normal-weight, compared to two women at baseline. At follow-up, four women had a BMI corresponding to class 1 obesity compared to nine at baseline. Furthermore, in the diet and exercise intervention groups, women experienced a 7.54% and 5.17% weight loss from baseline to follow-up. Of the 20 women that attended follow-up, 14 experienced an overall weight loss of >5% and three experienced an overall weight loss of >10%. A 5% reduction in body weight is considered clinically meaningful in regard to improving weight-related outcomes (Wilkinson, van der Pligt, Gibbons, & McIntyre, 2015), and a >10% weight reduction is known to induce further improvements in comorbid conditions, for example, lower incidences of systolic and diastolic BP, HDL cholesterol, obstructive sleep apnoea, type 2 diabetes and depression (Ryan & Yockey, 2017). Furthermore, with the knowledge that weight retention at one year postpartum is a significant contributor to the development of long-term obesity (Endres et al., 2015), which is estimated to account for up to 20% of cancers (De Pergola & Silvestris, 2013), the findings from this lifestyle intervention are extremely encouraging as a successful strategy has been developed and delivered to promote substantial weight loss in postpartum women and, if maintained, lower the risk of these women developing weight-related conditions, such as cancer, in later life. Much previous work has failed to show significant reductions in body weight, either from baseline to post-intervention or between intervention and control groups (Falciglia et al., 2017; Gilmore et al., 2017; LeCheminant et al., 2014; Østbye et al., 2009a; Walker et al., 2012; Wilkinson et al., 2015), which may be due to the lack of involvement of postpartum women in the design and delivery of such interventions. The work delivered in this thesis has identified appropriate and accepted approaches for the delivery of postpartum lifestyle interventions that should be adopted when supporting other women in the postpartum space.

It is possible that the offspring and partners of these women may also be positively impacted by the effects of this body of work. It is known that, compared to children with normal weight parents, children from families with obese parents are at a significantly higher risk of obesity (Bahreynian et al., 2017). Moreover, partners of pregnant women also experience weight gain during pregnancy and the postpartum period (Condon, Corkindale, & Boyce, 2004; Garfield et al., 2016), and weight loss interventions have shown to have a positive "ripple" effect on the BMI of untreated partners in the home (Golan, Schwarzfuchs, Stampfer, & Shai, 2010; Gorin et al., 2014). As such, the intervention delivered in this thesis has not only demonstrated a reduction in the incidence of obesity in mothers, but also has the potential to improve the BMI and associated health outcomes of their partners and children if women demonstrate long-term weight loss management or continued weight loss.

Furthermore, the approaches adopted herein have the potential to be far reaching given that the body of work involved a total of 47 postpartum women and obtained insights into the views and opinions of both primiparous and multiparous women of all BMI status. Whilst the work delivered in Chapters 3 and 5 was restricted to primiparous women, the lack of such restrictions in the PPI work (Chapter 4) has allowed an enhanced understanding of the physical activity and dietary experiences, and opinions on the design of a lifestyle intervention in 20 postpartum women who were of mixed BMI status and parity. Thus, the co-designed intervention detailed in this thesis can also be delivered to multiparous women; which demonstrates the reach of this body of work.

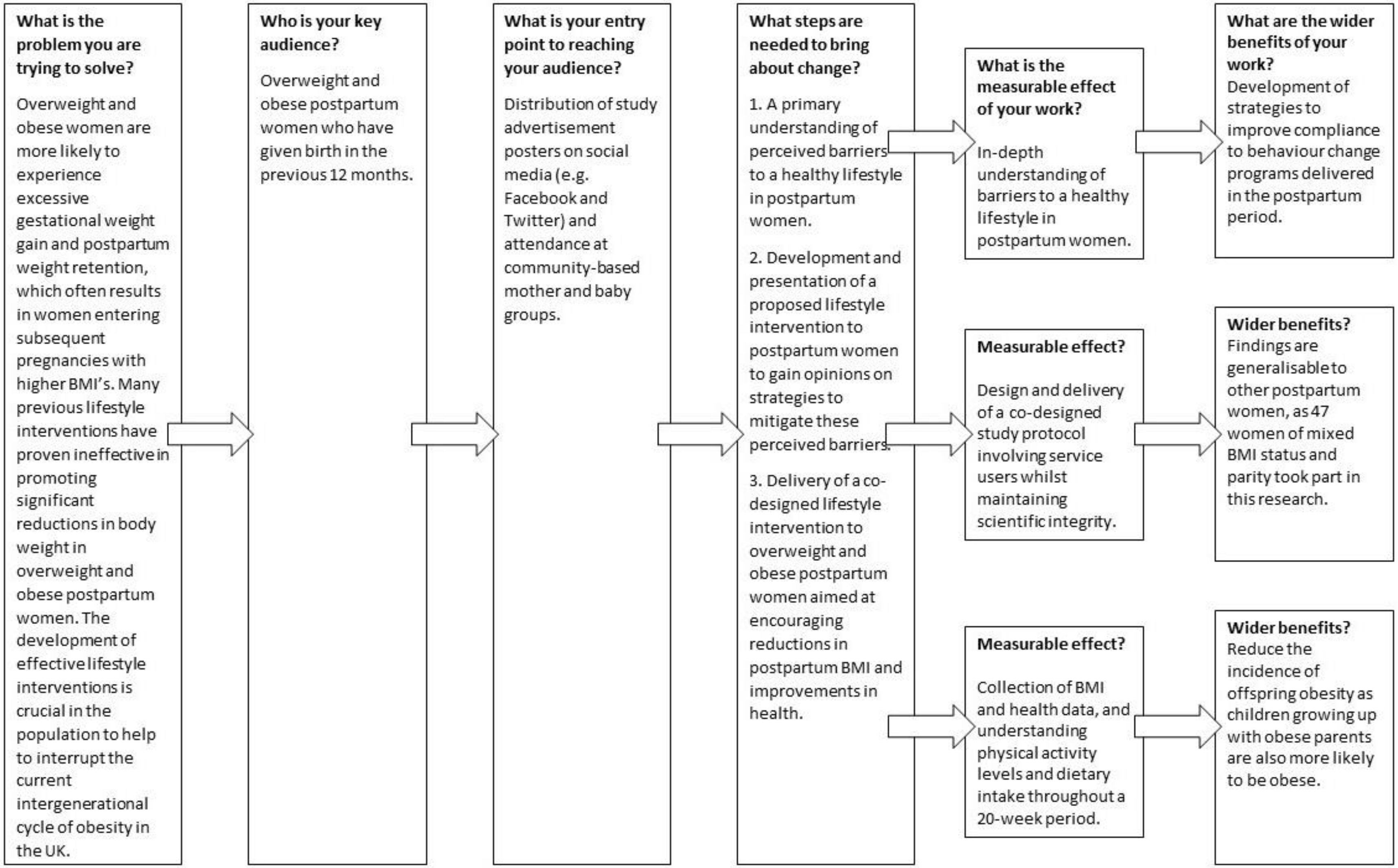

Figure 7.1 Theory of Change Logic Model for the current body of work (adapted from Nesta, 2011). This model shows the reach and impact of this work.

7.3 Limitations

Currently, there is a gap between research-based knowledge and clinical practice. Healthcare professionals working in postpartum care have stated that a lack of knowledge prevents them from providing appropriate weight management advice to postpartum women (N. Heslehurst et al., 2014). As such, they need to be educated and kept up-to-date on research findings such as the one described in this thesis. Therefore, in order not to limit the reach and impact of the work described herein, a comprehensive and accessible dissemination strategy is needed, such that this work can be used to benefit the intended end-users.

Whilst the work completed in this thesis involved service users (*i.e.*, postpartum overweight and obese women) in the co-design of a lifestyle intervention and demonstrated great success, it did not incorporate general practitioners (GP's), midwives, and other healthcare professionals. As such, some of translational potential of this work might not have been maximised.

A diverse and inclusive sample population is needed, given that maternal obesity in the UK is most prevalent in Black ethnic groups and in women living in socially deprived areas (N Heslehurst et al., 2010). Only three of the 47 women included in this thesis were from ethnic minority groups. As such, issues exist regarding the applicability of the findings to postpartum women from all ethnic backgrounds. Generally, those who volunteered to take part in the included studies were also from more highly educated backgrounds and those less well educated women were recruited through the help of family members who saw recruitment posters on social media and who were members of staff in relevant institutions (*e.g.*, where mother and baby groups were held). Given previous work showing that more highly educated individuals engage in healthier lifestyle behaviours compared to lower educated persons and have a greater awareness of the importance of a healthy lifestyle (Cutler & Lleras-Muney, 2010; Margerison-Zilko & Cubbin, 2013; Pampel, Krueger, & Denney, 2010), it would be plausible to suggest that they also volunteer to take part in such studies aimed at improving dietary and exercise behaviours and reducing BMI. The work in this thesis has demonstrated this pattern of recruitment, which creates uncertainty regarding the application of findings to all postpartum women, irrespective of ethnicity and educational levels.

The COVID-19 pandemic adversely impacted upon the completeness of some data sets in the intervention study (Chapter 5). Associated lockdown restrictions meant that it was impossible to conduct any laboratory-based measures (*i.e.*, DXA scans, blood samples) in the final four months of the study, which subsequently only allowed, for example, the analysis of full DXA datasets (visits 1, 2, 6 and 7) from six participants. Furthermore, whilst participants were initially asked to collect girth measurements with the help of a partner, these were also removed from the final analysis due to the unreliable nature of the data.

7.4 Future Research Directions

This thesis has highlighted that a co-designed lifestyle intervention was effective in encouraging significant reductions in body weight from baseline to follow-up. Given the restraints of the PhD programme, it was, however, only possible to include a 4-week follow-up period. As previously discussed, a lifestyle intervention delivered by Huseinovic et al. (2016) was successful in encouraging significant reductions in bodyweight at 1-year follow-up and at 2 years in women who had not experienced another pregnancy in this time (Huseinovic et al. 2018), when compared to a control group. Future work should now look to determine the long-term effects of the type of lifestyle intervention detailed in this thesis.

In Chapter 5, women were asked to choose if they wished to take part in a dietary or exercise intervention. This element of choice was included given findings from Chapter 4 demonstrating that postpartum women find it too overwhelming to attempt to alter both diet and exercise simultaneously. The majority of women enrolled in the lifestyle intervention did, however, seek to improve the other aspect of behaviour (diet or exercise) once they felt they had successfully incorporated the first set of changes into their lifestyle. Previous work has been completed to understand the effect of simultaneous and sequential introduction of lifestyle behaviours in pregnant women (Nagpal et al., 2019), and showed that the sequential introduction of exercise change strategies followed by dietary change strategies can improve adherence to behaviour change programs, compared to a simultaneous approach or one that introduces diet first. In the future, work investigating these simultaneous and sequential strategies should be completed in postpartum women to determine the most efficacious approach to encourage postpartum weight loss and healthy maternal and offspring outcomes.

In Chapter 5, there were no significant changes in any of the DXA variables when analysing group x time interactions, but there was a significant increase in FFM between visit 2 (pre-intervention) and visit 7 (follow-up) when analysing the combined lifestyle (diet and exercise) group. It is probable that the closure of laboratories as a result of the COVID-19 pandemic had an impact on results from body composition assessments as only six of 20 women who completed the study underwent DXA scans at visits 1, 2, 6 and 7 as initially planned. Previous work has also shown that only women enrolled in diet interventions, and not exercise interventions, experience healthy changes in measures of body composition following weight loss programmes (Amorim Adegboye et al., 2007; Bertz et al., 2012). Therefore, future work should: i) determine the effect of the current diet and exercise interventions on body composition assessments when not impacted by the COVID-19 pandemic, and ii) explore the design of exercise interventions, specifically the mode, intensity and frequency of prescribed exercise, to attempt to identify efficacious approaches to produce positive changes in postpartum body composition.

In Chapter 6, only around half of the women believed that the inclusion of text messages in the intervention had a positive influence on their results. As technology is more commonly used as a means to deliver healthcare advice, it is possible that, following pilot work aimed at determining the optimal tone and content of text messages, a text messaging service could be incorporated into routine postnatal care to encourage postpartum weight loss management with minimal additional time commitment from primary healthcare providers.

The intervention results (Chapter 5) presented in this thesis are extremely promising, however the adoption of up-scale approaches is now required to allow for the delivery of the intervention on a larger scale. Successful and acceptable aspects of the intervention design (*e.g.* use of WhatsApp groups to encourage social support, encouragement of regular self-weighing, inclusion of elements of autonomy) should be maintained, and up-scale strategies should align with those adopted in other UK-based studies. For example, a research midwife recruited 191 women from an inner-city maternity unit in the SWAN RCT (Bick et al., 2020), Lee, McInnes, Hughes, Guthrie, and Jepson (2016) recruited 65 women through NHS-methods (*e.g.* health visitors, baby clinics and breastfeeding groups) and community methods (*e.g.* baby groups, local libraries, local advertisements, community events), and Daley et al.

(2020) recruited postnatal women through general practices and Birmingham Women's Hospital. Daley et al. (2020) did however state that they only recruited 35% (28/80) of the original target sample, as such strategies must still be developed to improve adherence to and engagement with postnatal weight management programmes delivered in primary care settings in the UK.

7.5 Practical Applications

The findings presented in this thesis highlight the importance of involving service users in the design and delivery of weight loss programmes. This formative work is especially important with postpartum women, as they identify an array of barriers to a healthy lifestyle (as detailed in Chapter 3) during this time, which, through the delivery of PPI work (Chapter 4), were mitigated to encourage substantial post-intervention weight loss outcomes (Chapter 5). The diet and exercise interventions detailed in Chapter 5 should be delivered to other postpartum women as it is known that: i) the design of the interventions is accepted by postpartum women, ii) the interventions produce extremely favourable outcomes, and iii) women are satisfied as participants in the study and would recommend it to other new mothers. The findings also demonstrate the importance of social support in the postpartum period. For example, group-based support was encouraged through the inclusion of the WhatsApp group in Chapter 5, as it is known that group programmes produce greater weight loss (Borek, Abraham, Greaves, & Tarrant, 2018) and encourage greater accountability (Rogers, Lemstra, Bird, Nwankwo, & Moraros, 2016) than individual programmes. On many occasions throughout the intervention period there was minimal input from the service delivery team as it was evident that women were supporting each other in such a positive manner that substantial engagement with the group was not deemed necessary. As such, following the delivery of the intervention on a larger scale, strategies to incorporate group-based support into postnatal care pathways should be explored.

The present findings demonstrate that it is crucial to provide women with autonomy over lifestyle choices in the postpartum period, in order to encourage weight loss during this time. Findings from the exit questionnaire in Chapter 6, showed that 90% of women believed that being offered the choice of being part of the diet or exercise intervention had a positive influence on their results. In line with the Self Determination Theory Model of Health

Behaviour Change, previous work has shown that when individuals feel autonomous in regulating their behaviour they experience higher levels of competence when initiating and maintaining health behaviour change (Williams, McGregor, Zeldman, Freedman, & Deci, 2004), and experience long-term physical activity maintenance (Knittle et al., 2016; Ng et al., 2012). In primary care settings, the delivery of weight management advice in the postpartum period should, therefore, allow women to feel autonomous over their behaviours whilst feeling adequately supported to incorporate such changes into their lifestyles.

Regarding support, results from the exit questionnaire (Chapter 6) demonstrated that 79% of postpartum women believed that being part of a WhatsApp group with other mothers had a positive influence on their study outcomes. Furthermore, 100% of women believed that their results were positively impacted upon due to having the use of a Fitbit for the duration of the intervention. In agreement, previous work has demonstrated high acceptability from the use of technology-based support in postpartum women (Waring et al., 2018), and activity trackers are well accepted by various populations, including adolescents (Ridgers et al., 2018), older adults (McMahon et al., 2016; Valenzuela et al., 2018), and chronic disease and cancer populations (Mercer et al., 2016; Nguyen et al., 2017; Rossi et al., 2018). The use of group-based support, specifically from other mothers, and the use of objective measures of physical activity should be regarded as key approaches when encouraging postpartum weight loss in overweight and obese women.

7.6 Conclusion

The findings of this thesis have highlighted that, following an understanding of perceived barriers to a healthy lifestyle in the postpartum period and the co-creation of a dietary and exercise intervention, overweight and obese women experience clinically significant reductions in weight, reductions in dietary energy intake, and improvements in physical activity levels. Although overweight and obese women described an array of barriers to exercise and healthy eating in the postpartum period, the work in this thesis has demonstrated that, with the crucial input of postpartum women it is possible, unlike much previous work, to develop and deliver effective lifestyle interventions that successfully reduce BMI and improve health behaviours in overweight and obese women after childbirth.

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APPENDICES

APPENDIX 3A

PARTICIPANT INFORMATION SHEET

(Version 1.1, Date 13/04/2018)

Project title:

Perceived barriers to exercise and healthy dietary behaviours in overweight and obese postpartum women.

My name is Stephanie Hanley and I am a PhD candidate at Nottingham Trent University. My PhD will examine the effects of exercise and dietary interventions on weight management during and following pregnancy. However, limited attention has been given to really understanding the perceived barriers to healthy eating and exercise that pregnant women and new mums face. Such information is really important to ensure that we understand what women are experiencing and are able to design appropriate dietary and exercise guidance and support (the aim of the remaining studies of my PhD). By participating in this study you will be able to help me, and other researchers, to understand this and, hopefully, to help improve the lifestyles, pregnancy outcomes and weight management strategies of pregnant women and new mums.

1. What is the purpose of the study?

The purpose of this study is to gain an understanding of the perceived barriers to physical activity and healthy eating habits in women during and following pregnancy. The specific research questions to be answered are:

1. What are the exercise behaviours and perceived barriers to exercise in overweight and obese postpartum women?
2. What are the dietary behaviours and perceived barriers to healthy eating in overweight and obese postpartum women?
3. What behaviours and perceived barriers to exercise and healthy eating do overweight and obese women encounter during pregnancy?

4. How does physical activity and dietary experiences influence a woman's quality of life?

Postpartum: following childbirth

Physical activity: any bodily movement produced by skeletal muscles that requires energy expenditure e.g. walking, pushing the buggy, climbing stairs, gardening

2. Why have I been chosen?

It is likely that you may be experiencing, or have experienced, a number of barriers in relation to exercise engagement and healthy eating, especially during and following your pregnancy. Potentially, with your help in the study, it will be possible to develop effective postpartum weight management practices with the inclusion of physical activity and healthy eating behaviours in your daily lifestyle. Your inclusion in the study is entirely voluntary and you have the right to withdraw at any time up until the specified date at the top of this information sheet, without fear of penalty.

3. What will happen to me if I take part?

You will be required to attend the Clifton Campus of Nottingham Trent University for approximately one hour. Alternatively, if attending Clifton Campus is problematic for you, it is possible for me to visit you at your own home. During the visit you will be asked to complete two questionnaires regarding your physical activity levels and eating habits. You will also take part in a one to one interview with me regarding your current exercise and eating behaviours and perceived barriers, now and during your pregnancy. It is hoped that you will feel comfortable enough to talk about your feelings and experiences. This interview will be audio recorded for analysis purposes.

4. What are the possible disadvantages of taking part?

Although it is hoped you will not become distressed during the interview, we recognise that answering questions on physical activity and diet might cause you some stress or anxiety. To reduce the chance of this happening you are free to choose not to participate in the study, not to answer certain questions in the interview, or to stop the interview at any time.

5. What are the possible benefits of taking part?

The purpose of the study is to gain a better understanding of the physical activity and nutritional experiences of women during and following their pregnancies. Such information can be used to help educate medical practitioners regarding the experiences of new mothers and to help them to better support individuals with regards to changing physical activity and nutritional behaviours. Thus, in participating in this study you will hopefully be helping other pregnant women and new mums.

Nutritional: relating to the process of providing or obtaining the food necessary for health and growth

6. Will my taking part in the study be kept confidential?

Your participation in the study and the results obtained will be treated with the strictest confidence. Myself and my supervisor (Dr Kirsty Elliott-Sale) will be the only people who have access to the questionnaire and interview data. Your name and any identifying information will be removed from all results.

7. What if I have any questions?

If you have any other questions or require further information about any aspect of the study, please do not hesitate to contact me (or Kirsty) on the details provided below.

Contact Details:

Stephanie Hanley (PhD candidate): stephanie.hanley2016@my.ntu.ac.uk

Dr Kirsty Elliott-Sale (Supervisor): kirsty.elliottsale@ntu.ac.uk

APPENDIX 3B

Participant Statement of Consent to Participate in the Procedure Entitled:

‘Perceived barriers to exercise and healthy dietary behaviours in overweight and obese postpartum women’

1) I, __________________agree to partake as a participant in the above procedure.

2) I understand from the participant information sheet, which I have read in full, and from my discussion(s) with Stephanie Hanley that I will be completing two postnatal questionnaires regarding my physical activity levels and eating habits. I will then take part in an interview during which I’ll be asked questions related to my current exercise and eating behaviours and perceived barriers, now and during my pregnancy. I understand that I will be required to give up approximately one hour of my time, depending on how long the interview lasts.

3) It has also been explained to me by Stephanie Hanley that the risks and side effects which may result from my participation are as follows: I may become distressed during the interview as questions regarding physical activity and diet could cause me some stress or anxiety. I am aware that I can choose not to participate in the study, not to answer certain questions in the interview, or to stop the interview at any time.

4) I confirm that I have had the opportunity to ask questions about the procedure and, where I have asked questions, these have been answered to my satisfaction.

5) I undertake to abide by University regulations and the advice of researchers regarding safety.

6) I am aware that I can withdraw my consent to participate in the procedure at any time up until the date specified on the participant information sheet and for any reason, without having to explain my withdrawal and that my personal data will be destroyed.

7) I understand that any personal information regarding me, gained through my participation in this procedure, will be treated as confidential and only handled by individuals relevant to the performance of the study and the storing of information thereafter. Where information concerning myself appears within published material, my identity will be kept anonymous.

8) I confirm that I have had the University's policy relating to the storage and subsequent destruction of sensitive information explained to me. I understand that sensitive information I have provided through my participation in this procedure, in the form of questionnaires and interview responses will be handled in accordance with this policy.

9) I confirm that I have completed the health questionnaire and know of no reason, medical or otherwise that would prevent me from partaking in this research.

Participant signature: Date:

Independent witness signature: Date:

Primary Researcher signature: Date:

APPENDIX 3C

Interview Guide

Thank you for agreeing to take part in the interview today. I want to remind you that you have the right to withdraw from the study at any time and if there are any questions that you don't want to answer, you don't have to. I'll be asking you about your experiences with physical activity [exercise] and food in general and before, during and after pregnancy and I shall be recording the whole interview. The interview should last about an hour. Are you happy for the interview to be recorded and have you got any questions before we get going?

*The overall purpose of this interview, in line with narrative research, is to seek stories from the participants. In response to these stories some questions might be adapted and further probes used.

Introductory Questions

- Did the birth go to plan? / Was it what you expected?
- How are you feeling since the birth?

Main Questions (Physical Activity)

- When I say the words "physical activity" what comes to mind?
- What is your overall experience with physical activity? Do you have good or bad memories?
  - Probe: positive, negative, growing up, recently
- Can you tell me any stories related to physical activity? Recently, before or during your pregnancy?
- Can you tell me about your physical activity experiences before pregnancy?
- What was your physical activity like in each of your trimesters? Were there any changes as you progressed through your pregnancy?
- What is your physical activity like now?

Main Questions (Nutrition/Food)

- When you think about "nutrition/food" what comes to mind?

- Can you tell me any stories that stand out related to your diet/what you eat?
    - Probe: recently, younger, during pregnancy
- What are your overall experiences with food?
    - Probe: positive, negative
- Are you able to tell me about your dietary experiences at different stages during your pregnancy?
    - Probe: trimester changes, cravings, amounts
- What are your overall thoughts about what you eat?
- What changes in your diet have you noticed since the birth?
-

<u>Summary Questions</u>

- How does food and exercise affect you in general?
    - Probe: emotions, thoughts, feelings, quality of life
- How does physical activity and food relate to your quality of life?
- How has your quality of life been [changed] since the birth?
- Is there anything else you want to say or tell me about?

Thank you so much for participating in the interview.

APPENDIX 5A

Miss Stephanie Hanley
Erasmus Darwin Building Room 259
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Participant Information Sheet

Study Title:

The Effects of Exercise and Dietary Interventions in Overweight and Obese Postpartum Women on Weight Management and Health.

Please read the following information before discussing question/concerns with the chief investigator. **Participation is voluntary. You may chose not to participate, or withdraw your participation at any point, without having to specify a reason.**

Introduction & Purpose

The study will investigate how being part of an exercise or healthy eating programme affects patterns of weight change and other markers of physical and psychological health in women with overweight and obesity after pregnancy. It is well known that exercise and a balanced diet are the two main ingredients of a healthy lifestyle. It is also known that autonomy (choice) has a positive influence on behaviour change when included as part of a lifestyle intervention, however this has yet to be investigated in women with overweight and obesity. Therefore, this study aims to investigate the effects of either a self-selected exercise or dietary intervention on weight management and health in overweight and obese postpartum women. The results of this study may lead to a better understanding of weight loss programmes in overweight and obese postpartum women, helping to develop successful strategies when assisting this population in their weight loss efforts.

Participant Requirements

If you object to any of the procedures in the current trial please inform the chief investigator as soon as possible.

Inclusion Criteria

To be eligible to take part, you must:

- Be 18-50 years old at the date of your first visit.
- Have a body mass index (BMI) of greater than 25 $kg{\cdot}m^2$ (we can work this out for you using your height and body weight).
- Have had a singleton pregnancy.
- Have had one pregnancy to date.
- Be 6 weeks-1 year postpartum (and had physician's approval to return to exercise).
- Own a smartphone (able to download and use WhatsApp).
- You must in the researcher's opinion, be able and willing to follow all trial requirements.

Exclusion Criteria

Unfortunately, you will not be able to take part if any of the following apply to you:

- Have a clinical diagnosis of depression/postnatal depression.
- Currently enrolled on another weight loss programme.
- Currently consuming weight loss tablets/supplements.
- Have heart/liver/chronic renal disease.
- Have a clinical diagnosis of Type 2 Diabetes Mellitus.
- Consume excessive amounts of alcohol (regularly drinking more than 14 units of alcohol a week).
- Actively trying for another baby/planning a pregnancy in the next 6 months.

- Experienced a stillbirth.
- Have any health conditions that affect physical activity engagement.
- On any medication that affects the ability to exercise.
- On any medication that affects the ability to follow a healthy eating programme.

Study Location

You will be asked to attend Nottingham Trent University's Clifton Campus on seven occasions over a 20-week period. It may be possible to arrange a home visit for visits 3, 4 and 5 if this is easier for you. Visits 1, 2, 6 and 7 will last approximately 1.5 hours and visits 3, 4 and 5 will last between 30 minutes and 1 hour (around 8-10 hours in total).

Testing Restrictions

You will be required to come into the labs fasted; having not eaten or consumed caffeine since the previous evening. Where possible, all lab visits will be arranged between 9am and 11am. You will however be allowed to drink water in the morning before your visit. The reason for this is that some of the blood sample measures (glucose/cholesterol) are affected by what you eat and drink in the hours leading up to the test and we want to ensure as accurate results as possible.

Study Protocol

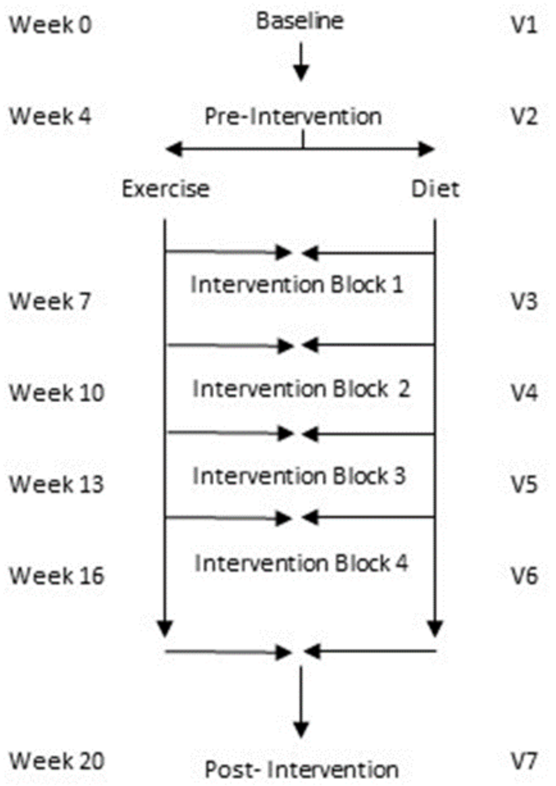

Figure 1: Outline of the study design and duration. V = Visit Number.

Visit 1: Baseline

The chief investigator will explain what participation would involve, and how data obtained from participants will be used/stored. The procedures for documenting adverse/serious adverse events throughout the study will be explained. You will have the opportunity to ask any questions/raise any concerns regarding taking part. If satisfied, you will be asked to complete an informed consent form, a health screen and history questionnaire, and a physical activity readiness questionnaire. Both of these questionnaires will be reassessed at every visit. You will then have the following measures taken:

1. Height and weight (BMI)
2. Girths- hip, waist, thigh, calf, bust, upper arm
3. DXA Scan (see below)
4. Fingertip Blood Sample (see below)
5. Blood Pressure

6. Resting Heart Rate

You will also be required to complete a series of questionnaires assessing quality of life, physical activity, eating behaviours, sleep and postnatal depression. Following this, you will be provided with a Fitbit Flex 2 and encouraged to maintain your current lifestyle for the next 4 weeks.

Visit 2: Pre-Intervention

The same measures as visit 1 will be taken on arrival to the laboratory during week 4 of the study. You will then watch a short video detailing the exercise and dietary interventions and will be free to ask any questions about the structure/delivery of the interventions. You will be given 24 hours to choose which intervention you wish to be part of during which time you will be encouraged to contact the main researcher by telephone/email or you will be contacted after 24 hours to determine your decision. At this point an information pack detailing the specifics of the first 4 weeks of the intervention will be sent in the post and you will be added to a prior created WhatsApp group related to either the dietary or exercise intervention. You will be able to retain the Fitbit for the duration of the intervention.

Visit 3-5: Intervention 1, 2 and 3

At each three-weekly visit of the intervention the following measures will be taken; height and weight (BMI), blood pressure, resting heart rate and questionnaires. You will be provided with intervention-specific information aimed at improving diet OR increasing physical activity levels at each three-weekly visit. Further information will also be placed on the WhatsApp group by the research team. You will also receive three text messages a week specific to your intervention and fourth text where you will be asked how you are getting on and if necessary, a phone call will be arranged.

Visit 6: Intervention 4

The same measures as taken in visits 1 and 2 will be taken during week 16. At this point, you will not be provided with any new information but will be encouraged to maintain/further increase your commitment to the intervention for the next 4 weeks. You will have the option to retain your Fitbit for the next 4 weeks, but you will be withdrawn from the WhatsApp group and will not receive any text messages/phone call support.

Visit 7: Post-Intervention

You will be invited to the lab during week 20 and the full set of measures will be repeated.

As well as the information detailed above, in the week before visits 2-7 you will receive two unannounced phone calls where you will be asked to recall all food and drink that you have consumed in the previous 24 hours.

After Participation: Formal Debrief

During your final visit, the chief investigator will explain how data obtained from you will be used (e.g. research publications, conference presentations), and how you will be able to access any publications/reports of the research. Procedures for withdrawing yourself and/or your data following trial completion will be explained.

<u>DXA Scan</u>

Body composition measurement using a DXA scan is a simple test that provides a comprehensive look at your body fat, muscle mass and bone. A DXA scan will provide you with a better understanding of how your fat tissue and muscle are distributed, allowing us to identify any health risks and accurately track changes in body composition. During the scan, you will lie flat on the scanning bed and be scanned in a straight line from head to toe. The scan normally takes 5-20 minutes. The amount of radiation delivered from all the DXA procedures equates to about 2 days natural background radiation, or the additional cosmic radiation incurred by flying to Spain. Public Health England would deem this risk trivial [Less than 1 in 1,000,000] and adds almost nothing to your natural lifetime risk of getting cancer of 50%. Please note however, that if for whatever reason you do not wish to undergo any of the DXA scans you are able to withdraw from this measure and still take part in the study. Your GP will be informed in cases where any previously undiagnosed conditions are discovered through the DXA scan (e.g. osteoporosis).

Please initial the box if you wish to withdraw from all DXA scans at this point. ☐

Fingertip Blood Sample

We require a small quantity (less than 1 teaspoon) of blood from you on your 1st, 2nd, 6th and 7th visits so we can measure the levels of different metabolites (small molecules) in the blood. The blood sample will be taken from the tip of your finger and will involve us making a very small puncture in your finger (the size of the tip of a needle) in order to obtain the sample. The procedure should take no longer than 5 minutes. Although rare, you may experience a slight discomfort when providing the blood sample and a small bruise on the finger afterwards.

Participant Responsibility

You are kindly asked to complete all documents accurately, and to follow all guidelines throughout the study. If completed accurately, the information from this study may help develop new strategies of assisting women with overweight and obesity to lose weight and improve overall health following pregnancy.

Potential Benefits

You will receive a large amount of information and support regarding strategies to improve your lifestyle after having a baby. You will undergo an in-depth assessment of health on seven occasions throughout the 20-week period.

Risks

As explained previously, you may experience a slight discomfort when providing the blood sample and a small bruise on the finger afterwards, however this is rare. Appropriate pressure will be applied to the puncture site following the blood sample to minimise the likelihood of bruising.

It is hoped that you will undergo a DXA scan on four different occasions during the study. The amount and level of radiation emitted by the DXA is small and equivalent to the amount of radiation you receive on a flight to Europe. The risk level is defined as negligible (so small that it may safely be disregarded).

Injury & Trial Complaints Procedure

In the event of injury/illness caused by negligence by the research team, you may contact the Research Sponsor for independent advice (Professor Barbara Pierscionek, Associate Dean for Research, Barbara.Pierscionek@ntu.ac.uk).

Travel Reimbursement

Travel reimbursements will be provided to you in accordance with NTU's policy (e.g. £0.25 per mile for travel by car, regardless of distance covered).

Pregnancy During Participation

If you become pregnant during the trial you will be withdrawn immediately.

Data Protection

Electronic data will be collected using a unique code, preventing participant identification, and stored on password-protected computers/user accounts at Nottingham Trent University, using a secure online server only accessible by the research team. Data may be retained for up to 5-10 years, but will be destroyed when no longer required, in line with Data Protection Legislation. If publications containing your data have already been submitted/approved following your withdrawal from the trial, the chief investigator will ensure your data is not included in any future publications. If you would like a copy of the data obtained from you, please contact the Chief Investigator.

Participant Signature:	Date:
Chief Investigator Signature:	Date:

If you have any questions/concerns please contact the research team using the contact details below.

Miss Stephanie Hanley **(Chief Investigator)**	**Dr. Kirsty Elliott-Sale** **(Senior Researcher)**
Nottingham Trent University	Nottingham Trent University
School of Science and Technology	School of Science and Technology
Erasmus Darwin, Room 259	Erasmus Darwin, Room 244D
Clifton, Nottingham	Clifton, Nottingham
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APPENDIX 5B

CONSENT FORM

Title of Project: The Effects of Exercise and Dietary Interventions in Overweight and Obese Postpartum Women on Weight Management and Health.

Name of Researcher: Miss Stephanie Hanley

Please initial box

1. I confirm that I have read the information sheet dated................... (version............) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected. ☐

3. I understand that relevant sections of my medical notes and data collected during the study, may be looked at by individuals from Nottingham Trent University, from regulatory authorities or from the NHS Trust, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records. ☐

4. I understand that the information collected about me will be used to support other research in the future, and may be shared anonymously with other researchers. ☐

5. I agree to my General Practitioner being informed of my participation in the study. / I agree to my General Practitioner being involved in the study, including any necessary exchange of information about me between my GP and the research team. ☐

6. I confirm that I have read the information regarding the DXA scan, have been given the opportunity to ask questions and agree to take part in this measure. ☐

7. I agree to take part in the above study. ☐

Name of Participant	Date	Signature
Name of Person Taking Consent	Date	Signature

APPENDIX 5C

FAQ's

What if I'm struggling to find the time to incorporate the changes into my diet?

Start slowly and plan your food when you have a spare few minutes in the day. It may be beneficial to do the weekly shop at the weekend so you're prepared for the week ahead.

What if I want to go out for food?

Plan your day around eating out and try to make healthy choices e.g. swap chips for baked/boiled potatoes and swap pies/sausages for chicken/fish

What if I have any other questions?

Please get in touch– that's what we're here for!

Useful Tips

- Try to introduce snack swaps one by one– it will make it easier to incorporate into your diet in the long-term.
- Remember that you're not obliged to only focus on portion sizes/healthy snacking. Feel free to change up other areas of your diet if you feel it necessary.
- Don't worry if you fall off track– don't give up, just get back on it the next day.

REMEMBER...

Simple alterations to your diet can make a big difference!

Try to replace full fat milk with semi-skimmed in your cereal/hot drinks.
Use the same milk in a hot chocolate and leave off the cream and marshmallows.

Contact Information

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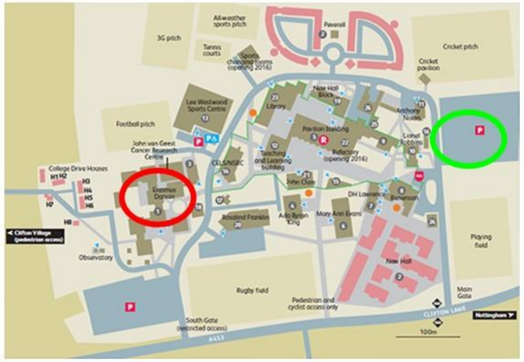

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Nutrition Guidance Part 1

NOTTINGHAM TRENT UNIVERSITY

NHS

Breastfeeding and Diet

- You don't need to eat anything special while you're breastfeeding. But it's a good idea for you, just like everyone else, to eat a healthy diet.

A healthy diet includes:

* At least 5 portions of a variety of fruit and vegetables a day, including fresh, frozen, tinned and dried fruit and vegetables, and no more than one 150ml glass of 100% unsweetened juice.
* Starchy foods, such as wholemeal bread, pasta and potatoes.
* Plenty of fibre from wholemeal bread and pasta, breakfast cereals, rice, pulses such as beans and lentils, and fruit and vegetables.
* Protein, such as lean meat and chicken, fish (at least 2 portions per week, including oily fish), eggs, nuts, seeds, soya foods and pulses.
* Dairy foods, such as milk, cheese and yoghurt– these contain calcium and are a source of protein.
* Non-dairy sources of calcium suitable for vegans include tofu, brown bread, pulses and dried fruits.

3 Week Plan

Part 1

Reduce Portion Sizes

Tips to reduce portions without increasing hunger…

1. Fill at least half your plate with vegetables
2. Eat protein with every meal or snack
3. Drink water with your meal
4. Use smaller plates
5. Eat mindfully (pay attention to what you're eating)
6. Eat more soluble fibre (e.g. top wholegrain oatmeal with diced apple or pear, add beans to soups, add chia seeds to yoghurts/cereal)
7. Don't pick at leftovers/child's plate
8. Check food labels for the correct portion sizes– it may be different to what you normally serve yourself
9. Finish your meal with fruit rather chocolate

British Heart Foundation

Part 2

Healthy Snacking

Top tips for healthy snacking…

1. Watch the amount of fat, saturated fat, salt and sugars in your snacks, as well as calorie content (see food label leaflet for more information)
2. Replace the sweets and biscuits in the cupboards with unsalted nuts and plain popcorn
3. Avoid shopping when hungry
4. Listen to hunger cues– are you eating because you're actually hungry or are you eating in response to your emotions?
5. Number of snacks– if you are snacking several times a day think about the meals you're eating and when
6. Use the Eatwell Guide to help identify healthier snacks and make sure snacks compliment other foods eaten during the day



APPENDIX 5D

FAQ's

What if I want to do some more research around the area?

Go ahead– please seek information from reputable sources (e.g. NHS/British Nutrition Foundation/British Heart Foundation)

What if I find a food that I'm not sure is healthy?

Check the nutrition label using the information provided and if you're still not sure then get in touch with us (contact details on back page).

What if I need some more recipe ideas? Ask other mums on the WhatsApp group for inspiration and look out for the weekly posts on the group.

What if I want to increase my exercise levels as well?

Go for it– a healthy lifestyle involves both a balanced diet and sufficient physical activity. If necessary, you should be looking to increase physical activity as well as altering your diet.

REMEMBER...

It won't always be easy!

If you have a bad week just think about all that you've achieved so far.

Use the WhatsApp group as a 'pick me up' when things aren't going so well– everyone's in this together.

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APPENDIX 5B

Version 1.1
12/06/2019

Nutrition Guidance Part 2

Each serving (150g) contains

Energy	Fat	Saturates	Sugars	Salt
1046kJ 250kcal	3.0g	1.3g	34g	0.9g
	LOW	LOW	HIGH	MED
13%	4%	7%	38%	15%

of an adult's reference intake
Typical values (as sold) per 100g: 697kJ/ 167kcal

NOTTINGHAM TRENT UNIVERSITY

NHS

Benefits of a Balanced Diet

- Weight loss

Losing weight can help to reduce the risk of chronic conditions.

- Reduced cancer risk

Diets rich in fruits, vegetables, and fibre have been shown to lower the risk of different cancers.

- Diabetes management

Eating a healthy diet can help a person with diabetes to manage blood glucose levels, keep blood pressure and cholesterol within target ranges and prevent or delay diabetes complications.

- Heart health and stroke prevention

Up to 80% of cases of premature heart disease and stroke can be prevented by making healthy lifestyle changes.

- Healthier children

Children learn most health-related behaviours from the adults around them, and parents who model healthful eating tend to pass these on.

- Strong bones and teeth

Keeping the bones healthy is vital in preventing osteoporosis and osteoarthritis in later life

3 Week Plan

Part 1

Reduce Red Labels

Choose products with green/amber labels and stick to recommended portion sizes

1. 'kJ' or 'kcal' (calories) = total energy (**daily intake = ~2,000kcal**)
2. Saturates/saturated fat content (**daily intake = no more than 20g**)
3. Total salt intake = **no more than 6g a day.** If 'sodium' is shown rather than salt multiply the amount on label by 2.5
4. Reference Intake (RI) = **guideline** to help you make **healthy dietary choices** and **balance your daily intake**
5. Serving/portion size = manufacturer's recommendation for one portion of the product (**It's important that you stick to this as much as possible**)

Part 2

Food Substitutes

Substitute regular foods with low-fat/ low sugar alternatives.

Replacing high calorie/high fat foods with lower fat/lower calorie choices is a great way to lose or maintain weight and build healthy lifetime habits.

For example… (**see leaflets for more**)

HIGHER FAT FOODS	LOWER FAT ALTERNATIVE
Pasta with cheese sauce	Pasta with tomato/ vegetable sauce
Ground beef	Ground turkey
Oil-packed tuna	Water-packed tuna
Donuts, muffins, scones, pastries	English muffins, bagels, reduced fat or fat-free muffins or scones
Nuts	Popcorn
Ice cream	Frozen yoghurt/sorbet
Regular butter/ mayonnaise	Light/reduced fat butter/mayonnaise
Granola	Bran flakes
Whole milk	Skimmed/semi-skimmed milk

APPENDIX 5E

Useful Tips

- By incorporating the suggested changes into your daily life it should make it easier to maintain in the long-term– try to get into a routine and this should help
- Support from family members should also help– ask for some help with the cooking
- Go to the supermarket with a list and stick to it– this way you won't buy things you don't need and won't get tempted by unhealthy foods on offer
- You know exactly what's going into homemade recipes so try when you can to make food from scratch.
- If you're going out for the day pack some snacks so you don't get tempted by pre- packaged high-fat/high sugar snacks in cafes/shops

REMEMBER...

You can always make what you eat that little bit healthier without losing out on flavour!

Can you add some spices to it?

Can you substitute one part of the meal for fruit/vegetables?

Can you change the way you cook the dish and cut out on the cooking oil?

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APPENDIX 5C

Version 1.1

12/06/2019

Nutrition Guidance Part 3

NOTTINGHAM TRENT UNIVERSITY

NHS

Eatwell Guide

- The Eatwell Guide shows the proportions in which different types of foods are needed to have a well-balanced and healthy diet
- The proportions shown are representative of your food consumption over the period of a day or even a week, not necessarily each meal time.
- The guide applies to most people regardless of weight, dietary restrictions/ preferences or ethnic origin
- You can use the guide to help you make healthier choices whenever you're:
  - deciding what to eat
  - at home cooking
  - food shopping
  - eating out at a restaurant/cafe

3 Week Plan

Part 1

Eatwell Guide

Main messages

- Eat at least 5 portions of a variety of fruit and vegetables every day
- Base meals on potatoes, bread, rice, pasta or other starchy carbohydrates; choosing wholegrain varieties where possible
- Have some dairy or dairy alternatives (e.g. soya); choosing lower fat and lower sugar options
- Eat some beans, pulses, fish, eggs, meat and other proteins (including 2 portions of fish every week, one of which should be oily)
- Choose unsaturated oils and spreads and eat in small amounts
- Drink 6-8 cups/glasses of fluid a day
- If consuming foods and drinks high in fat, salt or sugar have these less often and in small amounts

Part 2

Healthy Swaps (Lunch/Dinner)

Substitute current lunch/dinner choices with healthier alternatives.

Replacing high calorie/high fat mealtime foods with healthier alternatives is a great way to improve your diet without making any drastic changes.

For example… (**see leaflets for more**)

INITIAL CHOICE	HEALTHIER ALTER-
White bread	Wholegrain/multiseed bread
Fried crisps	Baked crisps
Chocolate bar	Kit-Kat
Chicken & bacon sand-wich	Ham salad sandwich
Cheese on toast	Beans on toast (no but-ter)
Pasta + cheese sauce	Pasta + tomato sauce
Fried food	Grilled food
White potatoes	Sweet potatoes
Feta cheese	Cottage cheese

APPENDIX 5F

FAQ's

What if I don't have the time to eat breakfast?

A healthy breakfast is an important part of a balanced diet, and provides some of the vitamins and minerals we need for good health. Therefore, try when you can to designate time to eat breakfast. Homemade low-fat/low sugar breakfast bars are a good substitute if you do need to eat on the go.

What if I'm going away and won't be able to stick to my diet completely?

Eat as healthy as you can whilst still maintaining the changes you've made but don't get hung up about it if you have a bad day or two– just don't let all the hard work to this point go to waste.

What if I'm not noticing any differences in my weight?

Don't worry– if you're making all the necessary changes and staying strict with yourself it will come. How's your physical activity? Can you look to increase this?

REMEMBER…

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APPENDIX 5D

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12/06/2019

Nutrition Guidance Part 4

NOTTINGHAM TRENT UNIVERSITY

Eight tips for Healthy Eating

https://www.nhs.uk/live-well/eat-well/eight-tips-for-healthy-eating/

1. Base your meals on starchy carbohydrates (1/3 of the food you eat)
2. Eat lots of fruit and veg (aim for at least 5 portions of a variety of fruit and veg every day)
3. Eat more fish (aim for at least 2 portions of fish a week, including 1 portion of oily fish)
4. Eat less salt (no more than 6g a day)
5. Get active and be a healthy weight (if you need to lose weight aim to eat fewer calories and be more active)
6. Don't get thirsty (aim for 6-8 glasses a day– low sugar choices, no more than 150ml fruit juice)
7. Don't skip breakfast (People who regularly eat breakfast are more likely to be a healthy weight)
8. Cut down on saturated fat and sugar

   -no more than 20g saturated fat a day

   -food product labels:

   22.5g/100g sugar = HIGH

   5g or less/100g = LOW

3 Week Plan

Part 1

Healthy Breakfast

CEREALS:

* Choose cereals that contain wholegrains and are low in sugar, fat and salt
  - high in sugar (see previous page)
  - high in fat = 17.5g or more/100g
  - high in salt = 1.5g or more/100g
* Some brands use the traffic light (green/amber/red) coding so remember to stay clear of the red labels where possible
* Serve cereal with semi-skimmed/skimmed milk or low-fat yoghurt
* Having cereal is a good opportunity to get one of your 5 a day. Raisins, dried apricots, bananas and strawberries are all popular choices.

OTHER:

* Swap white bread for wholemeal bread
* Swap regular jam and honey for no added sugar varieties
* Smoothies are a good means of getting more fruit and veg into your diet but be aware of sugar content (**See leaflet for more information**)

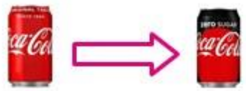
Part 2

Healthy Swaps (Drinks)

There are lots of hidden calories and sugar in drinks. Making simple swaps can reduce your calorie intake without making any drastic changes to your diet.

For example… (**see leaflets for more**)

139 kcal 39g sugar

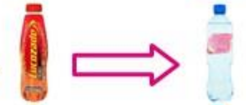


0 kcal 0g sugar

1 pump = 338 kcal 84g sugar

1tsp= 2kcal 0g sugar

93 kcal 11.3g sugar



8 kcal 1g sugar

50ml= 53 kcal 11.5g sugar

50ml= 3 kcal 0.4g sugar

250ml= 40 kcal 9g sugar

250ml= 0 kcal 0g sugar

*****REMEMBER… All food and drinks should be consumed in moderation*****

APPENDIX 5G

FAQ's

How quickly should I be walking?

Moderate intensity to start with (raised heart rate and still able to hold a conversation). As the program progresses in the coming weeks the intensity should increase to allow you to get the most out of it as you adapt to the exercise.

What if I want to go on more walks?

Go for it– this is just the target for the next 3 weeks but nobody will stop you if you want to do more!

What if I have any other questions?

Please get in touch– that's what we're here for!

Useful Tips

- Try to introduce daily activity swaps one by one– it will make it easier to incorporate into your daily lifestyle.
- Want something a little different? If you have the time and childcare, swimming is an excellent whole body exercise and has very little load bearing on your joints.
- Don't worry if you fall off track with the swaps/walking- just get back on it the next day.

REMEMBER...

Simple alterations to everyday life can make a big difference!

Can you do 10 squats while the kettle boils?
How many step ups can you do on the bottom step of the stairs in 1 minute?
How long can you hold a plank for?

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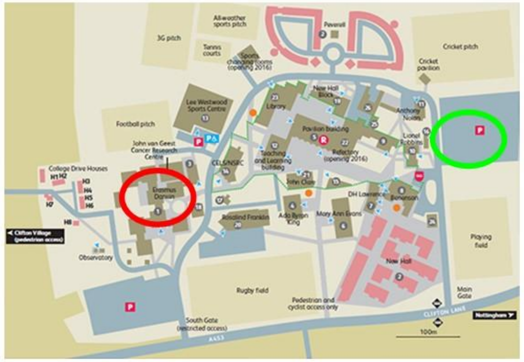

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APPENDIX 10A Version 1.1
12/06/2019

Exercise Guidance Part 1

NOTTINGHAM TRENT UNIVERSITY

NICE National Institute for Health and Care Excellence

Postpartum Guidelines

- Usually, if the pregnancy and birth has been uncomplicated a medical professional will give you the all clear to exercise at the 6-8 week postnatal check.
- You are encouraged to perform 30 minutes of moderate intensity exercise on a minimum of 5 days per week.
- This 30 minute session can be split into multiple shorter (10 minute) sessions if preferred.
- It is advised that activity levels are gradually increased over time until required activity level and duration is achieved.
- Physical activities, such as walking, should be built into daily life.
- Sedentary activities such as sitting in front of the television for long periods of time should be avoided.
- If you are breastfeeding exercise will not affect the quantity or quality of the milk.

3 Week Plan

Part 1

Daily Physical Activity Swaps

There are lots of ways to increase physical activity levels during your normal day. Moving more every day will help you get fitter and is easy to fit into your daily routine.

Example Daily Swaps

- Get off the bus one stop early and walk to your destination
- Walk to the shops instead of driving
- Get up and walk around after sitting for 30 minutes
- Take the stairs instead of the lift/escalator when you don't have the baby
- Go for a walk with a friend instead of meeting for coffee
- During TV ad breaks do squats, sit-ups or march on the spot until the programme comes back on

AIM: ↓ SITTING TIME ↑ MOVING TIME

Part 2

Walking

Your fitbit is your friend!

TARGET STEPS:

10% increase in daily steps from previous 4 weeks.

For example…

CURRENT DAILY STEPS	TARGET DAILY STEPS
3,000	3,300
3,500	3,850
4,000	4,400
4,500	4,950
5,000	5,500
5,500	6,050
6,000	6,600
6,500	7,150
7,000	7,700
7,500	8,250

Are you also able to go out for a brisk 10 - 15 minute walk 3 times a week with the aim of covering a quarter of your total daily steps?

APPENDIX 5H

FAQ's

How intense should the circuit exercises be?

Moderate intensity to start with (raised heart rate and still able to hold a conversation). Developing the proper technique is much more important at this point. Stop as soon as you are unable to perform the exercise properly.

What if I can't remember how to do the exercises?

Have a look at the instruction sheet or video links provided. If you're still unsure please get in touch.

What if I experience pain while doing the exercises?

Some muscle soreness during and in the 24/48 hours after exercise is normal. However, if you experience a sudden tightening in one area during an exercise (e.g. muscle cramps), soreness in your joints or any kind of pain that progressively gets worse you must stop exercising immediately and let us know.

REMEMBER...

Any exercise is better than none!

Continue to move more during the day and if you miss a session or two don't give up, just get back on it as soon as you can.

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APPENDIX 5B

Version 1.1

12/06/2019

Exercise Guidance Part 2

NOTTINGHAM TRENT UNIVERSITY

NICE National Institute for Health and Care Excellence

Postpartum Guidelines

REMEMBER...

- The aim by the end of the programme is to perform 30 minutes of moderate intensity exercise on a minimum of 5 days per week.
- These 30 minute sessions can be split into multiple shorter (10 minute) sessions if preferred.
- Increase activity levels gradually until the required activity level and duration is achievable.
- Activities such as walking and increasing standing time should be built into daily life.
- Sedentary activities such as sitting in front of the television for long periods of time should also be avoided.

Swapping 10 minutes of sitting for 10 minutes of activity can reduce the likelihood of developing cardiovascular disease and diabetes, and prevent premature death

3 Week Plan

Part 1

Circuits

Circuits are a set of exercises performed one after the other followed by a short period of rest. Typically, each set focuses on building the strength of one area of the body (e.g. legs/arms/abs).

Session time= 20-30 mins (x 2/3 sessions per week)

Total duration (per week) = **40-90mins**

Part 2

Walking

2 AIMS:

1. Target Steps= 10% increase in daily steps from previous 3 weeks

2a) Go on 4 brisk walks a week (or one more than the last 3 weeks)

b) Walk further than previous weeks in each 10-15min period (increase intensity)

Why Circuits?

- Circuits are a time-effective alternative to traditional exercise which mostly involves low to moderate intensity training of long duration.
- Compared to traditional exercise this form of exercise has been found to elicit greater improvements in fitness and a greater reduction in body fat percentage in individuals who are overweight or obese.

Circuits Session

(See instruction sheet if required)

Rest ≤ 2 minutes between sets

Set 1

20 Squats

10 Lunges (each leg)

20 March steps

Set 2

10 Pelvic bridges (hold for 5 seconds)

10 Abductor knee raises (each leg)

10 Bird dogs (each leg)

Set 3

10 Beginners push-ups

20 Mountain climbers

20-30 second plank

Complete Sets 1-3, two times.

APPENDIX 5I

FAQ's

What if I feel like I can't increase the intensity of the walking/circuits?

If the previous 3 weeks were as hard as you can manage and you would prefer to stick at the same intensity then that's completely fine. If on some days you can't manage the full session, don't worry about it– just do as much as you can.

What if I experience pain while doing the exercises?

A slight burning sensation that goes away when your muscles stop working is normal when associated with exercise, especially if you're new to the exercise. However, sharp pains in say your knees or ankles that don't go away are an indication to stop exercising and get in touch.

Useful Tips

- Use the WhatsApp group as a 'pick me up' when things aren't going so well– everyone's in this together.
- Other mums will love hearing how you're getting on– do you have any useful exercise tips? What's working for you in helping you to get/ stay active?

REMEMBER...

You're not obliged to stick to the program completely!

If you find an exercise class that may replace the circuits session or you would prefer to go for a swim rather than a walk then go for it!

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APPENDIX 5C

Version 1.1
12/06/2019

Exercise Guidance Part 3

NOTTINGHAM TRENT UNIVERSITY

NICE National Institute for Health and Care Excellence

Exercise Benefits

Exercise has so many benefits, some which you may never have been aware of.

For example, exercise...

1. Reduces body fat
2. Strengthens muscles
3. Manages chronic pain
4. Wards off viruses
5. Reduces diabetes risk
6. Strengthens heart
7. Clears arteries
8. Boosts mood
9. Improves memory
10. Improves coordination
11. Strengthens bones
12. Decreases stress
13. Boosts immune system
14. Lowers blood pressure
15. Reduces cancer risk

IMPORTANTLY...

15 minutes of exercise every day can add 3 years to your life.

3 Week Plan

Part 1

Circuits

Same sets of exercise as the last 3 weeks with a 4th bonus set if you can manage it.

REMINDER:

The circuits aren't supposed to be easy so push yourself as hard as you can while maintaining the correct technique on every exercise.

Session time= 30-40 mins (x 2/3 sessions per week)

Total duration (per week) = **60-120 mins**

Part 2

Walking

2 AIMS:

1. Target Steps= 10% increase in daily steps from previous 3 weeks

2a) Go on 5 brisk walks a week (or one more than the last 3 weeks)

b) Walk further than previous weeks in each 10-15 min period (increase intensity)

Circuits Session

(See instruction sheet if required)

Rest ≤ 2 minutes between sets

Set 1

20 Squats
10 Lunges (each leg)
20 March steps

Set 2

10 Pelvic bridges (hold for 5 seconds)
10 Abductor knee raises (each leg)
10 Bird dogs (each leg)

Set 3

10 Beginners push-ups
20 Mountain climbers
20-30 second plank

Complete Sets 1-3.
Then repeat sets TWICE more.

Bonus Set (See instruction sheet)

5 Step out burpees
15 Jumping jacks
20-30 second high knee walk/run on spot

Repeat set ONCE/TWICE.

APPENDIX 5J

Useful Tips

- Remember with the circuits sessions to do 3 exercises one after another without a break, or with as little rest as possible, followed by a rest of less than 2 minutes.
- Listen to your body. Don't exercise when you're feeling ill but push through any tiredness to fit in a session as it's bound to make you feel better afterwards.
- If the weather's rubbish and you don't fancy going out in the rain, do another circuits session to replace the walk.
- Arrange to walk with some of the other mums on the programme. And if you go for a coffee after try to refrain from having a cake– all that walking will go to waste!
- Are you seeing the results you want to? Are there any areas of your diet that can be improved as well as increasing your activity levels?

REMEMBER...

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APPENDIX 5D

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12/06/2019

Exercise Guidance Part 4

NOTTINGHAM TRENT UNIVERSITY

NICE National Institute for Health and Care Excellence

3 Week Plan

Part 1

Circuits

* The aim is to complete the core circuit set 4 times in each session.
* PLUS complete the bonus set once more than during the previous 3 weeks.

E.g. if you were able to complete it once last week try now to repeat it twice per session.

REMINDER:

If you don't have the time to do a full session any amount of exercise is better than none and you can always split the session up into two smaller sessions when you have a spare 20 minutes in the day.

Session time= ~45 mins (x 2/3 sessions per week)

Total duration (per week) = **90-135 mins**

How many minutes a week are you walking/doing circuits? How close are you to the magic 150 mins/week? Go on, push yourself a little bit more this week!

Part 2

Walking

2 AIMS:

1. Target Steps= 10% increase in daily steps from previous 3 weeks

2a) Go on 5-6 brisk walks a week (or one more than the last 3 weeks)

b) Walk further than previous weeks in each 10-15 min period (increase intensity)

Food for Thought

	CALORIES	BRISK WALK MINS
3 Custard Creams	171	39
Large Latte	118	27
Kettle Chips (30g)	151	34
1/4 Large Pizza	449	83
Snickers (48g)	245	56
Galaxy Bar (42g)	229	52
Sausage Roll (60g)	180	41
Blueberry Muffin	265	48
Tesco Cherry Bakewell Tart	215	49
Coca-Cola Can	139	32

Circuits Session

(See instruction sheet if required)
Rest ≤ 2 minutes between sets

Set 1
20 Squats
10 Lunges (each leg)
20 March steps

Set 2
10 Pelvic bridges (hold for 5 seconds)
10 Abductor knee raises (each leg)
10 Bird dogs (each leg)

Set 3
10 Beginners push-ups
20 Mountain climbers
20-30 second plank

Complete Sets 1-3.
Then repeat sets THREE MORE TIMES.

Bonus Set (See instruction sheet)
5 Step out burpees
15 Jumping jacks
20-30 second high knee walk/run on spot
Repeat set ONCE/TWICE/THREE TIMES.

APPENDIX 5K

Demographics Questionnaire

Participant Name	Participant Code	Visit/Trial Number	Date
[redacted]			

ABOUT YOU

1. **D.O.B.**
2. **Do you have any day-to-day support (e.g. partner, family, friends)?**

   Yes No

   Please state (e.g. mum, husband, best friend):
3. **Ethnic group**

   White

   Asian/Asian British

   Black/African/Caribbean/Black British

   Mixed/Multiple ethnic groups Please state:

   Other Please state:
4. **Occupation**
5. **Are you currently on maternity leave?**

   Yes No

   If yes,

   How long have you been on maternity leave?

   How long do you have to go?
6. **What is your highest qualification?**

   Please state (e.g. PhD, Masters, Degree, A levels, GCSE's):
7. **Are you breastfeeding?**

   Yes, currently No, had breastfed but stopped Never

   If you've now stopped breastfeeding, how long were you breastfeeding for?
8. **Did you receive any advice on physical activity/exercise while you were pregnant?**

   Yes No

If yes, from whom?

9. Did you receive any advice on physical activity/exercise after you had given birth?

Yes No

If yes, from whom?

10. Did you receive any advice on diet while you were pregnant?

Yes No

If yes, from whom?

11. Did you receive any advice on diet after you had given birth?

Yes No

If yes, from whom?

ABOUT BABY

1. **D.O.B.**
2. **Mode of delivery (e.g. natural, c-section, forceps)**
3. **Weight at delivery lbs oz g**
4. **Length of hospital stay days**

APPENDIX 5L

Medical Outcomes Study Questionnaire Short Form 36 Health Survey

This survey asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. Thank you for completing this survey! For each of the following questions, please circle the number that best describes your answer.

1. In general, would you say your health is:	
Excellent	1
Very good	2
Good	3
Fair	4
Poor	5
2. Compared to one year ago,	
Much better now than one year ago	1
Somewhat better now than one year ago	2
About the same	3
Somewhat worse now than one year ago	4
Much worse now than one year ago	5

3. The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

(Circle One Number on Each Line)

	Yes, Limited a Lot (1)	**Yes, Limited a Little (2)**	**No, Not limited at All (3)**
a. **Vigorous activities**, such as running, lifting heavy objects, participating in strenuous sports	1	2	3
b. **Moderate activities**, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1	2	3
c. Lifting or carrying groceries	1	2	3
d. Climbing **several** flights of stairs	1	2	3
e. Climbing **one** flight of stairs	1	2	3
f. Bending, kneeling, or stooping	1	2	3
g. Walking **more than a mile**	1	2	3
h. Walking **several blocks**	1	2	3
i. Walking **one block**	1	2	3
j. Bathing or dressing yourself	1	2	3

4. During the **past 4 weeks**, have you had any of the following problems with your work or other regular daily activities **as a result of your physical health**?

(Circle One Number on Each Line)

	Yes (1)	**No (2)**
a. Cut down the amount of time you spent on work or other activities	1	2
b. **Accomplished less** than you would like	1	2
c. Were limited in the **kind** of work or other activities	1	2
d. Had **difficulty** performing the work or other activities (for example, it took extra effort)	1	2

5. During the **past 4 weeks,** have you had any of the following problems with your work or other regular daily activities **as a result of any emotional problems** (such as feeling depressed or anxious)?

(Circle One Number on Each Line)

	Yes	**No**
a. Cut down the amount of time you spent on work or other activities	1	2
b. **Accomplished less** than you would like	1	2
c. Didn't do work or other activities as **carefully** as usual	1	2

6. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?	
Not at all	1
Slightly	2
Moderately	3
Quite a bit	4
Extremely	5

7. How much bodily pain have you had during the past 4 weeks?	
None	1
Very mild	2
Mild	3
Moderate	4
Severe	5
Very severe	6
8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?	
Not at all	1
A little bit	2
Moderately	3

Quite a bit	4
Extremely	5

These questions are about how you feel and how things have been with you **during the past 4 weeks**. For each question, please give the one answer that comes closest to the way you have been feeling. **(Circle One Number on Each Line)**

9. How much of the time during the **past 4 weeks** . . .

	All of the Time	**Most of the Time**	**A Good Bit of the Time**	**Some of the Time**	**A Little of the Time**	**None of the Time**
a. Did you feel full of pep?	1	2	3	4	5	6
b. Have you been a very nervous person?	1	2	3	4	5	6
c. Have you felt so down in the dumps that nothing could cheer you up?	1	2	3	4	5	6
d. Have you felt calm and peaceful?	1	2	3	4	5	6
e. Did you have a lot of energy?	1	2	3	4	5	6

	All of the Time	Most of the Time	A Good Bit of the Time	Some of the Time	A Little of the Time	None of the Time
f. Have you felt downhearted and blue?	1	2	3	4	5	6
g. Did you feel worn out?	1	2	3	4	5	6
h. Have you been a happy person?	1	2	3	4	5	6
i. Did you feel tired?	1	2	3	4	5	6

10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)? (Circle One Number)	
All of the time	1
Most of the time	2
Some of the time	3
A little of the time	4
None of the time	5

11. How TRUE or FALSE is each of the following statements for you.

(Circle One Number on Each Line)

	Definitely True	Mostly True	Don't Know	Mostly False	Definitely False
a. I seem to get sick a little easier than other people	1	2	3	4	5
b. I am as healthy as anybody I know	1	2	3	4	5
c. I expect my health to get worse	1	2	3	4	5
d. My health is excellent	1	2	3	4	5

APPENDIX 5M

Godin Leisure-Time Exercise Questionnaire

1. During a typical **7-Day period** (a week), how many times on the average do you do the following kinds of exercise for **more than 15 minutes** during your free time (write on each line the appropriate number).

Times Per Week

a) STRENUOUS EXERCISE
(HEART BEATS RAPIDLY) ________

(*e.g.*, running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, vigorous swimming, vigorous long-distance bicycling)

b) MODERATE EXERCISE
(NOT EXHAUSTING) ________

(*e.g.*, fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, popular and folk dancing)

c) MILD EXERCISE
(MINIMAL EFFORT) ________

(*e.g.*, yoga, archery, fishing from river bank, bowling, horseshoes, golf, snow-mobiling, easy walking)

2. During a typical **7-Day period** (a week), in your leisure time, how often do you engage in any regular activity **long enough to work up a sweat** (heart beats rapidly)?

OFTEN	SOMETIMES	NEVER/RARELY
1.	2.	3.

APPENDIX 5N

The Three-Factor Eating Questionnaire

Please read each statement and select from the multiple choice options the answer that indicates the frequency with which you find yourself feeling or experiencing what is being described in the statements below.

1. When I smell a delicious food, I find it very difficult to keep from eating, even if I have just finished a meal.

Definitely true (4)/ mostly true (3)/ mostly false (2)/ definitely false (1)

2. I deliberately take small helpings as a means of controlling my weight.

Definitely true (4)/ mostly true (3)/ mostly false (2)/ definitely false (1)

3. When I feel anxious, I find myself eating.

Definitely true (4)/ mostly true (3)/ mostly false (2)/ definitely false (1)

4. Sometimes when I start eating, I just can't seem to stop.

Definitely true (4)/ mostly true (3)/ mostly false (2)/ definitely false (1)

5. Being with someone who is eating often makes me hungry enough to eat also.

Definitely true (4)/ mostly true (3)/ mostly false (2)/ definitely false (1)

6. When I feel blue, I often overeat.

Definitely true (4)/ mostly true (3)/ mostly false (2)/ definitely false (1)

7. When I see a real delicacy, I often get so hungry that I have to eat right away.

Definitely true (4)/ mostly true (3)/ mostly false (2)/ definitely false (1)

8. I get so hungry that my stomach often seems like a bottomless pit.

Definitely true (4)/ mostly true (3)/ mostly false (2)/ definitely false (1)

9. I am always hungry so it is hard for me to stop eating before I finish the food on my plate.

Definitely true (4)/ mostly true (3)/ mostly false (2)/ definitely false (1)

10. When I feel lonely, I console myself by eating.

Definitely true (4)/ mostly true (3)/ mostly false (2)/ definitely false (1)

11. I consciously hold back at meals in order not to weight gain.

Definitely true (4)/ mostly true (3)/ mostly false (2)/ definitely false (1)

12. I do not eat some foods because they make me fat.

Definitely true (4)/ mostly true (3)/ mostly false (2)/ definitely false (1)

13. I am always hungry enough to eat at any time.

Definitely true (4)/ mostly true (3)/ mostly false (2)/ definitely false (1)

14. How often do you feel hungry?

Only at meal times (1)/ sometimes between meals (2)/ often between meals (3)/almost always (4)

15. How frequently do you avoid "stocking up" on tempting foods?

Almost never (1)/ seldom (2)/ moderately likely (3)/ almost always (4)

16. How likely are you to consciously eat less than you want?

Unlikely (1)/ slightly likely (2)/ moderately likely (3)/ very likely (4)

17. Do you go on eating binges though you are not hungry?

Never (1)/ rarely (2)/ sometimes (3)/ at least once a week (4)

18. On a scale of 1 to 8, where 1 means no restraint in eating (eating what you want, whenever you want it) and 8 means total restraint (constantly limiting food intake and never "giving in"), what number would you give yourself? ☐

Revised 18-Item (Karlsson et. Al. 2000)

APPENDIX 5O

PITTSBURGH SLEEP QUALITY INDEX (PSQI)

INSTRUCTIONS: The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1. During the past month, when have you usually gone to bed at night?

   USUAL BED TIME ______________________

2. During the past month, how long (in minutes) has it usually take you to fall asleep each night?

   NUMBER OF MINUTES ______________________

3. During the past month, when have you usually gotten up in the morning?

   USUAL GETTING UP TIME ______________________

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spend in bed.)

   HOURS OF SLEEP PER NIGHT ______________________

INSTRUCTIONS: For each of the remaining questions, check the one best response. Please answer all questions.

5. During the past month, how often have you had trouble sleeping because you...

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
(a) ...cannot get to sleep within 30 minutes	☐	☐	☐	☐
(b) ...wake up in the middle of the night or early morning	☐	☐	☐	☐
(c) ...have to get up to use the bathroom	☐	☐	☐	☐
(d ...cannot breathe comfortably	☐	☐	☐	☐
(e) ...cough or snore loudly	☐	☐	☐	☐
(f) ...feel too cold	☐	☐	☐	☐
(g) ...feel too hot	☐	☐	☐	☐
(h) ...had bad dreams	☐	☐	☐	☐
(i) ...have pain	☐	☐	☐	☐

(j) Other reason(s), please describe

____

____

How often during the past month have you had trouble sleeping because of this?	☐	☐	☐	☐

PSQI Page 1

	Very good	Fairly good	Fairly bad	very bad
6. During the past month, how would you rate your sleep quality overall?	☐	☐	☐	☐

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
7. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?	☐	☐	☐	☐
8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?	☐	☐	☐	☐

	No problem at all	Only a very slight problem	Somewhat of a problem	A very big problem
9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	☐	☐	☐	☐

	No bed partner or roommate	Partner/ roommate in other room	Partner in same room, but not same bed	Partner in same bed
10. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	☐	☐	☐	☐

If you have a roommate or bed partner, ask him/her how often in the past month you have had...

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
(a) ...loud snoring	☐	☐	☐	☐
(b) ...long pauses between breaths while asleep	☐	☐	☐	☐
(c) ...legs twitching or jerking while you sleep	☐	☐	☐	☐
(d) ...episodes of disorientation or confusion during sleep	☐	☐	☐	☐
(e) Other restlessness while you sleep; please describe	☐	☐	☐	☐

____

____

PSQI Page 2

APPENDIX 5P

Edinburgh Postnatal Depression Scale[1] (EPDS)

Name: ______________________________ Address: ___________________________

Your Date of Birth: ____________________ ___________________________

Baby's Date of Birth: ___________________ Phone: _________________________

As you are pregnant or have recently had a baby, we would like to know how you are feeling. Please check the answer that comes closest to how you have felt **IN THE PAST 7 DAYS**, not just how you feel today.

Here is an example, already completed.

I have felt happy:
☐ Yes, all the time
☒ Yes, most of the time This would mean: "I have felt happy most of the time" during the past week.
☐ No, not very often Please complete the other questions in the same way.
☐ No, not at all

In the past 7 days:

1. I have been able to laugh and see the funny side of things
   ☐ As much as I always could
   ☐ Not quite so much now
   ☐ Definitely not so much now
   ☐ Not at all

2. I have looked forward with enjoyment to things
   ☐ As much as I ever did
   ☐ Rather less than I used to
   ☐ Definitely less than I used to
   ☐ Hardly at all

*3. I have blamed myself unnecessarily when things went wrong
   ☐ Yes, most of the time
   ☐ Yes, some of the time
   ☐ Not very often
   ☐ No, never

4. I have been anxious or worried for no good reason
   ☐ No, not at all
   ☐ Hardly ever
   ☐ Yes, sometimes
   ☐ Yes, very often

*5 I have felt scared or panicky for no very good reason
   ☐ Yes, quite a lot
   ☐ Yes, sometimes
   ☐ No, not much
   ☐ No, not at all

*6. Things have been getting on top of me
   ☐ Yes, most of the time I haven't been able to cope at all
   ☐ Yes, sometimes I haven't been coping as well as usual
   ☐ No, most of the time I have coped quite well
   ☐ No, I have been coping as well as ever

*7 I have been so unhappy that I have had difficulty sleeping
   ☐ Yes, most of the time
   ☐ Yes, sometimes
   ☐ Not very often
   ☐ No, not at all

*8 I have felt sad or miserable
   ☐ Yes, most of the time
   ☐ Yes, quite often
   ☐ Not very often
   ☐ No, not at all

*9 I have been so unhappy that I have been crying
   ☐ Yes, most of the time
   ☐ Yes, quite often
   ☐ Only occasionally
   ☐ No, never

*10 The thought of harming myself has occurred to me
   ☐ Yes, quite often
   ☐ Sometimes
   ☐ Hardly ever
   ☐ Never

Administered/Reviewed by ______________________________ Date ___________________________

[1]Source: Cox, J.L., Holden, J.M., and Sagovsky, R. 1987. Detection of postnatal depression: Development of the 10-item Edinburgh Postnatal Depression Scale. *British Journal of Psychiatry* 150:782-786 .

[2]Source: K. L. Wisner, B. L. Parry, C. M. Piontek, Postpartum Depression N Engl J Med vol. 347, No 3, July 18, 2002, 194-199

APPENDIX 5Q

<u>Food Recall Instructions</u>

Midnight-Midnight

EXAMPLE:

intake24.co.uk/surveys/INT3

Username: P01

Password: newmum01

1. Types of food and drinks first- will ask for amounts later
2. Each food on a separate line- use arrow key
3. Commonly consumed (e.g. milk with tea)- don't enter twice if already entered
4. Press on meal name (e.g. 'Breakfast') to add/delete foods
5. Add another meal at bottom of recall
6. Some foods- choose closest match/rephrase
7. Homemade dish- all ingredients on separate lines
8. Commonly forgotten items- e.g. condiments/cooking oil/food on the go
9. Can log back in on same day- must be same device

APPENDIX 6A

Participant Information Sheet

DATE: 31/07/2020

Background Information

The lifestyle intervention that you recently took part in involved other postpartum women in the design of the study. These women highlighted that social support (e.g. WhatsApp group), self-monitoring (e.g. wearing a pedometer) and being offered the choice of engaging in either an exercise or diet intervention were amongst a number of aspects that they believed to be of great importance in encouraging positive post-intervention health outcomes. Therefore, we believe it is now important to gain feedback from the women that took part in the intervention study which will help to inform future work in the population. Furthermore, we are keen to understand what effect, if any, the COVID-19 pandemic has had on intervention engagement in those affected by it.

What is involved?

- Completion of a short online questionnaire about your thoughts and opinions of the lifestyle intervention that you recently took part in.
- Should take between 10 and 20 minutes to complete.

Who can take part?

- You must have taken part in the postpartum lifestyle intervention delivered by Miss Stephanie Hanley (PhD student) at Nottingham Trent University.

Participation and withdrawal

- Participation is voluntary, so it is up to you whether or not to take part.
- You should **read the full information sheet by clicking here** and if you have any questions you should ask a member of the research team.

- If you choose to participate, you are free to withdraw your data without giving a reason up to two weeks after completion of the questionnaire. If you wish to withdraw your data after data collection, you may do so by contacting a member of the research team and quoting your participant ID number (used during the lifestyle intervention and provided at the start of this questionnaire), at which point your data will be destroyed.

Confidentiality, data storage and access

- Data will be stored securely in password protected files on the main researcher's personal password-protected computer.
- Access to identifiable data will only be granted to the research team.
- Any data shared publicly will be non-identifiable.

If you agree to participate in the study outlined above, please complete the following screening questions and the informed consent form before proceeding to the questionnaire.

NOTTINGHAM TRENT UNIVERSITY

PARTICIPANT INFORMATION SHEET

Lifestyle Interventions in Overweight and Obese Postpartum Women: Post-Study Engagement Feedback

You are invited to take part in a research study exploring the thoughts and opinions of postpartum women following engagement in a lifestyle intervention aimed at improving weight management and health. The study involves participation in an online questionnaire, in which you will have the opportunity to share your thoughts regarding the design and delivery of the lifestyle intervention that you recently completed, including (if you were affected) the impact of the Covid-19 pandemic on your engagement in the intervention.

It is your choice if you take part in the study or not. If you choose not to participate you will not be disadvantaged in any way and you do not have to give a reason. Before you decide if you wish to participate, it is important that you understand what participation will involve and why the research is being conducted. Please take the time to thoroughly read this participant information sheet. Please contact a member of the research team if you have any questions.

Why are we doing the study?

Patient and Public Involvement (PPI) work, which refers to work carried out to obtain the thoughts and opinions of individuals prior to conducting research intended for their benefit, has been recommended as an important inclusion in research. However, little PPI work has been conducted with postpartum women. The lifestyle intervention that you recently took part in involved other postpartum women in the design of the study. These women highlighted that social support (e.g. WhatsApp group), self-monitoring (e.g. wearing a pedometer) and being offered the choice of engaging in either an exercise or diet intervention were amongst a number of aspects that they believed to be of great importance in encouraging positive post-intervention outcomes. Therefore, we believe it is now important to gain feedback from the women that took part in the intervention study which will help to inform future work in the population. Furthermore, we are keen to understand what effect, if any, the COVID-19 pandemic has had on intervention engagement in those affected by it.

What is involved?

The study will involve the completion of a short questionnaire about your thoughts and opinions of the lifestyle intervention that you recently took part in. The questionnaire should take 10-20 minutes to complete.

Who can take part?

You must have taken part in the postpartum lifestyle intervention delivered by Miss Stephanie Hanley (PhD student) at Nottingham Trent University.

Benefits of the research

The study may allow us to better understand aspects of a previously delivered postpartum lifestyle intervention that were effective/ineffective in promoting weight management and health in overweight and obese women. This information is vital in informing the design and delivery of future lifestyle interventions in the population. Also, understanding the impact of COVID-19 will help in our interpretation of the lifestyle intervention results.

Potential risks of the research

The risks involved in the study are low, although we acknowledge that thinking about your health and results from the lifestyle intervention study may be sensitive topics.

Participation and withdrawal

Participation is voluntary, so it is up to you whether or not to take part. You should read this information sheet and if you have any questions you should ask a member of the research team. You should not agree to take part in this research until you have satisfactory answers for any questions you may have. If you agree to participate after reading the participant information sheet, you should continue to complete the online questionnaire. Initially, you will be asked to provide consent regarding the use of data associated with this study. However, you may still withdraw your data without giving a reason up to two weeks after data collection by contacting a member of the research team and quoting your participant number from the intervention study, at which point all your data will be destroyed.

Confidentiality, data storage and access

Data will be stored securely in password protected files on a secure cloud server on the main researcher's personal password-protected computer. Access to identifiable data will only be granted to members of the research team, directly involved in the study. The anonymised dataset will be stored in a publicly available server to facilitate data sharing with other researchers who may be able to use the data for other relevant research. Any data shared publicly will be non-identifiable.

If you wish to ask any further questions regarding this study, please feel free to contact a member of the research team.

Contacts:

Miss Stephanie Hanley	Dr Kirsty Elliott-Sale
PhD Student	Associate Professor
School of Science & Technology	School of Science & Technology
Nottingham Trent University	Nottingham Trent University
Erasmus Darwin Room 259	Erasmus Darwin
Nottingham	Nottingham
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07414542237	0115 848 6338

APPENDIX 6B

Initial Screening

I confirm that I took part in the postpartum lifestyle intervention delivered by Stephanie Hanley at Nottingham Trent University (August 2019-June 2020). * Required

Yes

No

Informed Consent

I have read the participant information sheet provided and agree to participate in this project which involves the completion of an online questionnaire. * Required

Yes

I confirm that I have been provided with the contact information of the researchers and have had the opportunity to ask questions about the study and, where I have asked questions, there have been answered to my satisfaction. * Required

Yes

I am aware that I am free to withdraw my consent to participate in the study without giving a reason within two weeks of completing the questionnaire by providing my participant number from the lifestyle intervention that I recently completed at Nottingham Trent University. Following withdrawal, my personal data will be destroyed. * Required

Yes

I understand that any personal information regarding me, gained through my participation in this study, will be treated as confidential and only handled by individuals relevant to the performance of the study and the storing of information thereafter. Where information concerning myself appears within published material, my identity will be kept anonymous. * Required

Yes

I hereby fully and freely consent to my participation in this study. * Required

Yes

Unique ID Code

The following question is unrelated to the research question and will only be attached to your data. This ensures that you will remain anonymous throughout the research process, whilst still allowing us to withdraw your data should you request this. **Please make a note of your ID code for your records.**

Please provide us with the participant number that you were allocated when taking part in the lifestyle intervention led by Stephanie Hanley at Nottingham Trent University.

APPENDIX 6C

Exit Questionnaire

The following questions are in relation to the lifestyle intervention that you recently took part in at Nottingham Trent University led by Miss Stephanie Hanley. The answers you provide will help us to understand the results from the lifestyle intervention and will inform future research in the population.

1. On a scale of 1-5 how satisfied were you with the weight loss/results you achieved? (**1 = not satisfied at all, 5 = completely satisfied**)

   1 2 3 4 5
2. Did you enjoy being part of the WhatsApp group? **Yes/No/Not sure**
3. How did being part of the WhatsApp group influence your results? **Positively/Negatively/Neither positively nor negatively**
4. How did the text messages influence your results? **Positively/Negatively/Neither positively nor negatively**
5. Do you think the time between visits was sufficient (i.e. 3-4 weeks)? **Yes/No/not sure**
6. How do you think being given the choice of interventions influenced your results? **Positively/Negatively/Neither positively nor negatively**
7. Were you able to maintain the same levels of commitment and motivation (or further improve) in the final 4 weeks after the support had been withdrawn? **Yes/No/not sure**
8. How has your lifestyle changed since the study finished? **Positively/Negatively/Stayed the same**
9. On a scale of 1-5 how satisfied are you with your current lifestyle (diet and physical activity) and health now that the study has finished? (**1 = not satisfied at all, 5 = completely satisfied**)

   1 2 3 4 5

Please provide any further information regarding your answers above and the design and/or delivery of the lifestyle programme. Please feel free to comment on any aspect(s) of the study and provide any suggested amendments/additions. Your answers will be extremely useful in helping to inform future research in the population.

Please answer the following questions only if you were in the study when the COVID-19 pandemic started.

1. How did the pandemic affect your results in the study? **Positively/Negatively/Neither positively nor negatively**
2. How has the pandemic affected your diet? **Positively/negatively/no change**
3. How has the pandemic affected your physical activity levels? **Increased/decreased/no change**
4. How did the pandemic affect your commitment/motivation to make/continue with the necessary changes required to achieve your personal goals? **Positively/Negatively/Neither positively nor negatively**

Please provide any further information regarding your answers to the questions above and how you believe the pandemic has affected your study results.