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Author(s)	Flannery, Caragh
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DEVELOPING A BEHAVIOUR CHANGE INTERVENTION FOR PHYSICAL ACTIVITY DURING PREGNANCY

Caragh Flannery

BA (Hons.), MSc.

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School of Psychology, National University of Ireland, Galway

Thesis Supervision

Primary Supervisor
Professor Molly Byrne, Health Behaviour Change Research Group, School of Psychology, National University of Ireland, Galway

Supervisor
Professor Patricia M Kearney, ESPRIT Research Group, School of Public Health, University College Cork

Supervisor
Professor Fionnuala M McAuliffe, UCD Perinatal Research Centre, School of Medicine, University College Dublin, National Maternity Hospital, Dublin

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DECLARATION

I declare that this thesis has not been submitted as an exercise at this or any other university. I declare that this thesis is entirely my own work. The work, upon which this thesis is based, was carried out in collaboration with a team of researchers and supervisors who are duly acknowledged in the text of the thesis. The library may lend or copy this thesis upon request.

Signed:

Caragh Flannery

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STATEMENT OF CONTRIBUTION

The candidate was responsible for the design, data collection, analysis and write-up of each of the four studies conducted in this research. The supervisory team, Graduate Research Committee, co-authors and local experts advised and provided support in conducting the research.

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Also to my fellow classmate Siobháin O'Doherty,
May she rest in peace

RESEARCH OUTPUTS

The following manuscripts published or submitted for publication form the empirical chapters in the current thesis.

Papers relating to thesis

C Flannery, D Dahly, M Byrne, AS Khashan, S McHugh, LC Kenny, FM McAuliffe, PM Kearney. **Social, biological, behavioural and psychological factors and physical activity during pregnancy: a cross-sectional study** (BMJ Open – Revised and resubmit Feb 2019)

C Flannery, S McHugh, AE Anaba, E Clifford, M O'Riordan, LC Kenny, FM McAuliffe, PM Kearney, M Byrne. **Enablers and barriers to physical activity in overweight and obese pregnant women: an analysis informed by the theoretical domains framework and COM-B model.** BMC Pregnancy Childbirth. 2018;18(1):178.

C Flannery, S McHugh, L Kenny, MN O'Riordan, FM McAuliffe, C Bradley, PM Kearney, M Byrne. **Exploring obstetricians, midwives and general practitioners approach to weight management in pregnant women with a BMI ≥25: a qualitative study** *BMJ Open* 2019;**9:**e024808. doi: 10.1136/bmjopen-2018-024808

C Flannery, M Fredrix, E Olander, FM McAuliffe, M Byrne, PM Kearney. **Physical activity interventions for overweight and obesity during pregnancy: A systematic review of the effectiveness and content of behaviour change interventions** (International Journal of Obesity – under review)

Other publications relating to the thesis

C Hurst, C Flannery, M Byrne, PM Kearney, F Dunne, M O'Riordan, JC Walsh. **Investigating the Perceived Benefits, Barriers and Beliefs towards Physical Activity in Pregnancy among Women with Gestational Diabetes Mellitus**. Ir Med J. 2017;110(7):617.

C Flannery, M Mtshede, S McHugh, AE Anaba, E Clifford, M O'Riordan, LC Kenny, FM McAuliffe, PM Kearney, M Byrne, K Matvienko-Sikar. **Dietary behaviours and weight**

management: A thematic analysis of overweight and obese pregnant women's perceptions (Maternal and Child Nutrition - Ready for submission)

Additional non-thesis related publications published during the PhD

M Fredrix, J McSharry, C Flannery, S Dinneen, M Byrne. **Goal-setting in diabetes self-management: A systematic review and meta-analysis examining content and effectiveness of goal-setting interventions.** Psychol Health. 2018;33(8):955-77.

Published abstracts

P126 Lifestyle management and support during pregnancy: a qualitative study of the attitudes and experiences of pregnant women and healthcare professionals September 2016 Journal of Epidemiology & Community Health 70(Suppl 1):A109.1-A109 DOI:10.1136/jech-2016-208064.223

Experiences of lifestyle management and support during pregnancy: a qualitative study of the attitudes and experiences of pregnant women and healthcare professionals January 2016 Frontiers in Public Health 4 DOI: 10.3389/conf.FPUBH.2016.01.00093

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Research dissemination

Paper	Conference proceedings
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C Flannery, S McHugh, LC Kenny, M O'Riordan, FM McAuliffe, C Bradley, PM Kearney, M Byrne. **Exploring obstetricians, midwives and general practitioners approach to weight management in pregnant women with a BMI ≥25: a qualitative study**	*Oral Presentations* ▪ Aug 2018: European Health Psychology Society, National University of Ireland, Galway ▪ Nov 2017: School of Nursing and Midwifery Conference, University College Cork ▪ Jan 2017: 3rd Annual SPHeRE conference, Royal College of Surgeons Ireland, Dublin *Poster Presentations* ▪ Sept 2017: Society for Social Medicine Manchester, UK ▪ March 2017: 9th International DIP Symposium on Diabetes, Hypertension, Metabolic Syndrome & Pregnancy of which Maternal Medicine meets Fetal Medicine, Barcelona, Presented by Dr Mairead O'Riordan ▪ Oct 2016: New Horizons Translational Research

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C Flannery, M Fredrix, E Olander, FM McAuliffe, M Byrne, PM Kearney. **Physical activity interventions for overweight and obesity during pregnancy: A systematic review of the effectiveness and content of behaviour change interventions**	*Oral Presentation* ▪ June 2018: International Society of Behavioural Nutrition and Physical Activity, Hong Kong *Poster Presentation* ▪ Aug 2018: European Health Psychology Society, National University of Ireland, Galway

ABSTRACT

Background: Although the benefits of physical activity during pregnancy are well documented in the literature, women's activity levels often reduce or cease during pregnancy. Moreover, adherence to physical activity guidelines is particularly low for pregnant women with a Body Mass Index (BMI) ≥25kg/m².

Aim: The aim of this PhD is to enhance our understanding of physical activity during pregnancy with the view to inform the development of a theoretically based behaviour change intervention to improve physical activity levels for pregnant women with overweight and obesity.

Methods: Following the guidelines of the UK Medical Research Council Framework for developing complex interventions, four studies were conducted to address the three steps in the development phase of this framework. In the first study a cross-sectional analysis using the Screening for Pregnancy Endpoints (SCOPE) data was conducted. This study examined the impact of other health behaviours (fruit and veg consumption, fish consumption, smoking and alcohol) and psychological well-being (perceived stress scale, behavioural responses to pregnancy, state trait anxiety inventory, depression scale, and postnatal depression score) on physical activity levels during early pregnancy. Two qualitative studies were conducted, the first with pregnant women with overweight and obesity to identify enablers and barriers to physical activity using the theoretical domains framework and COM-B model (capability, opportunity, motivation and behaviour). And secondly with health care professional to understand how obstetricians, GPs and midwives engage with women with overweight and obesity during pregnancy. In the final study a systematic review and meta-analysis was conducted to identify and summarise the effectiveness of existing physical activity interventions for pregnant women with overweight and obesity with a specific emphasis on the behaviour change techniques employed.

Findings: Results from the cross-sectional analysis found that having more than 12 years of schooling and a higher socioeconomic status was related to moderate physical activity compared to low physical activity. From the qualitative interviews with pregnant women with overweight and obesity, knowledge was identified as a barrier to physical activity,

as women lacked information on safe activities during pregnancy and described the information they received from their midwife as ‘limited’. Social support was identified as a key enabler to physical activity; women are more likely to be physically activity if they received support from their family and friends. Health care professionals, described using a “*softly-softly approach”* to weight management in order to strike a balance between being woman-centred and empathetic and medicalising the conversation. Findings from the systematic review and meta-analysis, suggest that physical activity interventions are to some extent effective at increasing physical activity levels for pregnant women with overweight and obesity. The behaviour change technique ‘social support’ was identified for pregnant women with overweight and obesity within the included interventions. Additionally, ‘self-monitoring of behaviour’ (using items such as diaries, workbooks and pedometers to monitor physical activity) emerged as one of the most frequently used BCTs within the included interventions.

Conclusion:

The findings of this research contribute to a clearer understanding of physical activity, providing an in-depth exploration of the barriers, enablers and determinants of physical activity for pregnant women, providing important insights into this high-risk population and a thorough foundation for intervention development. Following the MRC framework and utilising frameworks from behavioural science, this research revealed factors such as ‘social support’, ‘goal setting’ and ‘self-monitoring of behaviour’ as important behavioural components that may have a positive impact on improving physical activity in future interventions. Future interventions should include women’s ‘social support’ networks and provide some form of ‘self-monitoring’ such as pedometers so that women can set goals and monitor their progress.

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
ACOG	American Congress of Obstetricians and Gynaecologists
AIC	Akaike Information Criterion
Apps	Mobile Device Software Applications
BCT	Behaviour Change Techniques
BIC	Bayesian Information Criterion
BCW	Behaviour Change Wheel
BMI	Body Mass Index
CMACE	Centre for Maternal and Child Enquiries
CI	Confidence Interval
COM-B	Capability, Opportunity, Motivation, Behaviour
CUMH	Cork University Maternity Hospital
EPDS	Edinburgh Postnatal Depression Scale
GP	General Practitioner
GDM	Gestational Diabetes Mellitus
GWG	Gestational Weight Gain
GPs	General Practitioners
HCP	Health Care Professional
HSE	Health Service Executive
IOM	Institute of Medicine
kg	Kilogram
MRC	Medical Research Council
MD	Mean Difference
OR	Odds Ratio
PBC	Perceived Behaviour Control
PA	Physical Activity
PRAMS	Pregnancy Risk Assessment Monitoring system
PSS	Perceived Stress Scale
RCT	Randomised Controlled Trial
RRR	Relative Risk Ratio
SCT	Social Cognitive Theory
SEI	Socioeconomic Index

STROBE	Strengthening the reporting of observational studies in epidemiology
SCOPE	Screening for Pregnancy Endpoints Data
STAI	State Trait Anxiety Index
TPB	Theory of Planned Behaviour
TRA	The Theory of Reasoned Action
TTM	Trans Theoretical Model
TDF	Theoretical Domains Framework
UK	United Kingdom
USA	United States of America
WHO	World Health Organisation

1 INTRODUCTION

1.1 Introduction overview

Excessive weight gain and obesity during pregnancy is an increasing public health concern. Maternal obesity, defined as a Body Mass Index (BMI) at first booking appointment ≥30kg/m^2, represents a significant and growing problem for pregnant women, babies and for health care professionals in obstetric practices (Dodd, Grivell, Crowther, & Robinson, 2010; Health Service Executive, 2013).

This chapter will review key themes relevant to this PhD research. It begins with the prevalence of maternal obesity, the definition of gestational weight gain and its consequences for maternal and child health. Research regarding different lifestyle factors, in particular physical activity, behaviour change interventions and interventions using technology are reviewed. Finally, the rationale for the current research will be presented, followed by the thesis outline.

1.2 Maternal obesity

Maternal obesity is defined as a BMI of ≥30kg/m^2 or more at the first antenatal consultation (Centre for Public Health Excellence at Nice National Collaborating Centre for Primary, 2006). BMI is a simple index of weight-for-height and is calculated by dividing a person's weight in kilograms by the square of their height in metres (kg/m^2)(Centre for Public Health Excellence at Nice National Collaborating Centre for Primary, 2006; World Health Organization, 2000).

Gestational weight gain is the total weight gained during pregnancy, with the most substantial weight gains occurring in the second and third trimester (Institute of Medicine, 2009). Excessive weight gain during pregnancy can be defined as gaining weight in excess of the recommendations. According to the World Health Organisation (WHO), BMI is classified as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2) in adults. Furthermore, there are three different classes of obesity: BMI 30.0–34.9 (Class I); BMI 35.0–39.9 (Class 2); and BMI 40 and over (Class 3 or morbid obesity), which recognise the continuous relationship between BMI, morbidity and mortality (Centre for Public Health Excellence at Nice National Collaborating Centre for Primary, 2006; World Health Organization, 2000).

The Institute of Medicine (IOM) recommends different gestational weight gain for each BMI category (Table 1) (Nascimento, Surita, Parpinelli, Siani, & Pinto e Silva, 2011; National Research Council, 2010). These guidelines are individualised to pre-pregnancy BMI and are based on evidence of weight gain patterns in pregnancy and on health outcomes for mother and baby. A recent review that compared national gestational weight gain guidelines and energy intake recommendations found that 31% of countries were adopting these gestational weight gain guidelines (Alavi, Haley, Chow, & McDonald, 2013). Furthermore, after two different searches of available guidelines, the authors of the review found no gestational weight gain guidelines or recommendations available for Ireland (Alavi et al., 2013).

In Ireland, the Health Service Executive (HSE) has published a 'Reference Guide for Primary Care' and 'Clinical Practice Guidelines', neither of which include recommended ranges of gestational weight gain in pregnancy (Health Service Executive, 2013; HSE/ICGP, 2013)

Table 1: IOM guidelines for total and rate of weight gain during pregnancy

	Total weight gain		**Rates for weight gain in 2nd and 3rd Trimester**	
Pre-pregnancy BMI	Range in kg	Range in lbs	Mean (range) in kg/week	Mean (range) in lbs/week
Underweight (<18.5kg/m^2)	12.5-18	28-40	0.51 (0.44-0.58)	1 (1-1.3)
Normal weight (18.5-24.9 kg/m^2)	11.5-16	25-35	0.42 (0.35-0.50)	1 (0.8-1)
Overweight (25.0-29.9 kg/m^2)	7-11.5	15-25	0.28 (0.23-0.33)	0.6 (0.5-0.7)
Obese (≥30 kg/m^2)	5-9	11-20	0.22 (0.17-0.27)	0.5 (0.4-0.6)

(Institute of Medicine, 2009)

1.2.1 Prevalence of maternal obesity

The WHO classifies obesity as one of the most critical health threats, affecting more than 10% of the adult population worldwide and causing the premature death of more than 2.8 million annually (World Health Organisation, Updated 2016). As obesity rises, maternal obesity becomes one of the most common risk factors seen in obstetric care (Mission, Marshall, & Caughey, 2013; O'Reilly & Reynolds, 2013). In 2013, an estimated one in five women in the world aged 20 years or older was obese (BMI≥30kg/m^2). Furthermore, obesity in women was most widespread in high income countries with a prevalence of 25% in the UK and 34% in the USA (Ng et al., 2014). In Europe, the prevalence of overweight and obesity among pregnant women ranged between 33% and 50% (World Health Organization, 2008)

In a recent prospective study in Dublin, where BMI was measured in the first trimester, 19% of women were categorised as obese (Fattah et al., 2010). Moreover, in a study conducted in Galway, 25% of women were found to be obese at their first antenatal visit (Lynch, Sexton, Hession, & Morrison, 2008). Similarly, high levels have been reported in Britain, 20% prevalence of obesity, 5% of whom with severe or morbid obesity and 35% obese in Australia (Dodd et al., 2010; Heslehurst et al., 2007a; Huda, Brodie, & Sattar, 2010; Oteng-Ntim, Varma, Croker, Poston, & Doyle, 2012). According to Heslehurst et al. (2007), in the UK, the proportion of obese women at the start of pregnancy increased significantly over time from 9.9 to 16.0% (Heslehurst et al., 2007a). Furthermore results from the Centre for Maternal and Child Enquiries (CMACE), who conducted a national audit of obesity during pregnancy in the UK, found that from a total of 128,290 women, 6413 were identified as having a BMI≥35kg/m^2 at any time during pregnancy (Public Health England, accessed 2015). International studies have shown maternal obesity ranging from 1.8% to 25.3% across a number of countries. However there is difficulty comparing international rates due to differences in BMI categories, thresholds and definitions (Public Health England, accessed 2015).

1.3 Health consequences

Having a high BMI in pregnancy is associated with a number of adverse maternal and neonatal outcomes (Johnson et al., 2013).

1.3.1 During pregnancy

During pregnancy and delivery, the maternal difficulties associated with obesity include gestational diabetes mellitus, gestational arterial hypertension and preeclampsia, venous thromboembolic disease, induction of labour and caesarean section. Gestational diabetes mellitus is defined as any amount of glucose intolerance with onset or first recognition during pregnancy (Johnson et al., 2013), and it has been shown that even minor degrees of carbohydrate intolerance are related to obesity (Renault et al., 2014). According to a systematic review, women who have had gestational diabetes mellitus have at least a seven-fold increased risk of developing type 2 diabetes mellitus in the future compared with those who have had a normoglycaemic pregnancy (Bellamy, Casas, Hingorani, & Williams, 2009). The prevalence of gestational diabetes mellitus is rising, increasing the concerns over the associated clinical risks and highlighting a major interest in prevention strategies, in particular, lifestyle interventions (Heslehurst et al., 2007a).

1.3.2 Labour

Furthermore, during labour, clinical and surgical complications can also occur, such as infections, haemorrhage, anaemia, urinary tract infection and endometritis; in addition obesity can also cause failure to progress in labour, shoulder dystocia and stillbirth (Galliano & Bellver, 2013; Guelinckx, Devlieger, Beckers, & Vansant, 2008).

1.3.3 Postpartum

Following delivery obese women are more likely to suffer postpartum haemorrhage, urinary incontinence, depression, difficulties breastfeeding and have extended hospital stays than women with a normal BMI 18-25 kg/m^2 (Guelinckx et al., 2008; Heslehurst et al., 2008; Li, Jewell, & Grummer-Strawn, 2003; Zain & Norman, 2008). Obesity also has adverse neonatal outcomes, such as macrosomia, metabolic syndrome, neural tube defects, congenital anomalies (LaCoursiere, Bloebaum, Duncan, & Varner, 2005) and a predisposition to obesity (Catalano & Ehrenberg, 2006), type 2 diabetes, cardiovascular disease and cancer in later life (Galliano & Bellver, 2013; Nelson, Matthews, & Poston, 2009).

1.3.4 Economic cost

The economic cost of obstetric care per obese pregnancy is increased as pregnancy-related complications can require extra and more specialised check-ups and more frequent and longer hospitalisations (Callaway, Prins, Chang, & McIntyre, 2006; Galtier-Dereure, Boegner, & Bringer, 2000). Research has indicated that the average cost of hospital prenatal care in France was five times higher in mothers who were overweight than in normal-weight control women (Galtier-Dereure et al., 2000). The duration of both day and night hospitalisation was also higher with women whose pregravid BMI ≥30kg/m^2 staying in the hospital an average of 4.43 more days than lean women. In Ireland, preeclampsia costs between €6.5 and €9.1 million per annum with women using more health services during their pregnancies (antepartum scans, caesarean sections, longer hospital stays for mother, and increased number of admissions and longer NICU stays compared with women without the condition)(Fox et al., 2017). These results highlight the high costs that excess maternal weight can have on health care services (Caldas et al., 2015; Galtier-Dereure et al., 2000).

1.4 Antenatal interventions

This increasing global problem of obesity in maternity care has led to national guideline recommendations for the development of interventions to improve pregnancy outcomes (Yaktine & Rasmussen, 2009). This advice stimulated many clinical trials, predominantly of behavioural interventions addressing diet and physical activity. However, most trials have been underpowered for clinical outcomes such as gestational diabetes focusing instead on gestational weight gain (Thangaratinam et al., 2012b). Nonetheless, systematic reviews of these mostly small trials suggest potential for the prevention of gestational diabetes in women with obesity (Rogozińska, Chamillard, Hitman, Khan, & Thangaratinam, 2015). While the negative impact of obesity on obstetric and perinatal outcomes is well established in the literature, research on how such adverse effects can be minimised through the use of effective interventions is lacking. In principle, weight status and weight gain can be improved through the encouragement of physical activity and the delivery of nutrition counselling during the period of obstetric care, and there is a growing body of research into effective forms of interventions (Smith, Cooke, & Lavender, 2012). There are many interventions aimed at promoting lifestyle changes throughout pregnancy (Williams & French, 2011); however, these lifestyle interventions are often varied and report inconclusive results. Furthermore, they often ignore the specific behaviour change techniques employed or relevant theories underlying the intervention, thus making it difficult for researchers and clinicians to understand the key transferable intervention components (Asbee et al., 2009).

Pregnancy has been identified as a unique screening and intervention opportunity for obese women as it is said to be a 'teachable moment' that can create positive outcomes for mother, baby and society (Phelan, 2010). The evidence suggests that pregnancy is a suitable time in which to intervene with regard to gestational diabetes, gestational weight gain and other lifestyle risk factors. Women may feel more empowered to make changes and may feel motivated to control their own weight if they realise that such changes may also benefit their child's health (Phelan, 2010; Smith et al., 2012; Thangaratinam et al., 2012a). Therefore, effective interventions, that include modifications of individual behaviour including dietary or exercise therapies, are needed to reduce gestational diabetes, gestational weight gain and improve overall maternal and neonatal health outcomes (Galliano & Bellver, 2013).

1.4.1 Gestational diabetes mellitus and gestational weight gain

The interventions targeting gestational diabetes and gestational weight gain range from dietary advice and counselling, promotion of physical activity, weight monitoring and or weight gain advice (Oostdam, van Poppel, Wouters, & van Mechelen, 2011). Many recent systematic reviews that incorporate a number of higher quality studies, which focus on gestational diabetes and gestational weight gain (Elliott-Sale, Barnett, & Sale, 2015; Muktabhant, Lawrie, Lumbiganon, & Laopaiboon, 2015; Shepherd et al., 2017; Tieu, Shepherd, Middleton, & Crowther, 2017). The most recent updated Cochrane systematic (2017) review included 23 randomised controlled trial (n=8918 healthy women) (Shepherd et al., 2017). Each of the 23 trials assessed an intervention for pregnant women that included both diet and exercise components compared with standard care. The review found a reduced risk of gestational diabetes in the diet and exercise intervention group compared with the usual care group (average risk ratio (RR) 0.85, 95% confidence interval (CI) 0.71 to 1.01; 6633 women; 19 RCT). Furthermore, the review found evidence of less gestational weight gain in the diet and exercise intervention group compared with the control group (mean difference (MD) -0.89 kg, 95% CI -1.39 to -0.40; 5052 women; 16 RCTs). The Cochrane review concluded that due to the variability of the diet and exercise components tested in the included studies, the evidence had limited ability to inform practice (Shepherd et al., 2017). Another systematic review of controlled trials summarised the effectiveness of different interventions to prevent gestational diabetes (Oostdam et al., 2011). The results indicated that dietary counselling can reduce the incidence of gestational diabetes, and that a low glycaemic index diet can reduce the risk of infants being born with a high birth-weight. It was demonstrated in a few trials that an exercise programme significantly reduced the rate of infants born with high birth weight, but had no effect on the levels of maternal fasting blood glucose or incidence of gestational diabetes. These results suggest that there may be some benefits of dietary counselling or an exercise programme but that better-designed studies were required to generate higher quality evidence. Other systematic reviews have looked at trials for pregnant women with overweight and obesity, suggesting that physical activity can help to limit gestational weight gain (Agha, Agha, & Sandall, 2014; Olander, Berg, McCourt, Carlström, & Dencker, 2015; Sui, Grivell, & Dodd, 2012).

Antenatal interventions often tend to be multicomponent with a combination of physical activity and diet (Guelinckx, Devlieger, Mullie, & Vansant, 2010). While targeting multiple behaviours in intervention programs have been found to be an efficient approach to enhance health and reduce health costs (Prochaska & Prochaska, 2011), some argue that attempting to influence numerous behaviours simultaneously may put high demands on participants (de Vries et al., 2008) and prove less successful compared to targeting a single behaviour. Others maintain that targeting multiple health behaviours would be more successful for achieving certain goals, while targeting single health behaviours is superior for achieving others (e.g., overall weight loss vs. targeted behaviour)(Nudelman & Shiloh, 2015; Sweet & Fortier, 2010).

Due to the increased health risk to pregnant women with overweight and obesity, some interventions have focused solely on these women (Shirazian, Monteith, Friedman, & Rebarber, 2010; Wolff, Legarth, Vangsgaard, Toubro, & Astrup, 2008); while others have recognised that all pregnant women are equally important to target. Although it may be important to target all pregnant women, some studies suggest that behaviour change interventions can impact women in healthy weight range differently to those in the overweight and obese range (Hui et al., 2006; Jeffries, Shub, Walker, Hiscock, & Permezel, 2009; Phelan et al., 2011; Polley, Wing, & Sims, 2002). In a recent randomised controlled trial (RCT) of healthy weight (n=201) and overweight or obese women (n=200), the healthy weight women receiving the intervention were significantly more likely than the healthy weight control group women to meet IOM weight gain recommendations (40.2% compared with 52.1%; $p = 0.003$). The intervention had no effect in overweight or obese participants, suggesting that different approaches may be required for different weight ranges in pregnancy (Phelan et al., 2011). These findings were consistent with several other studies of obese women (Asbee et al., 2009; Guelinckx et al., 2010; Jeffries et al., 2009). Thus, women in higher BMI categories need to be considered independently and provided with more intensive interventions (Phelan et al., 2011).

1.4.2 Digitally delivered interventions

The digital world is becoming an increasingly important means of sustaining health, with healthcare programmes now using advanced and available technology to deliver improved health outcomes (Abroms, Padmanabhan, & Evans, 2012). Mobile phones have been rapidly and widely adopted among virtually all demographic groups (Albabtain, AlMulhim, Yunus, & Househ, 2014). A review focusing on healthy pregnant women and technology for lifestyle interventions concluded that technology could aid current practices but that there is lack of high quality published evidence (O'Brien, McCarthy, Gibney, & McAuliffe, 2014). A pilot randomised control trial of a low-intensity web-based pedometer programme confirmed the results of the systematic review; that up take of a technology lifestyle intervention holds potential as a safe and sustainable tool to support behaviour change in pregnancy (Kim, Draska, Hess, Wilson, & Richardson, 2012; O'Brien et al., 2014). Technology such as mobile phones and mobile phone applications can be used to reach a wide population, can be tailored to the individual, can give instant delivery of the intervention and requires little technological knowledge, making it a promising means of delivering future health behaviour change interventions during pregnancy.

1.5 Physical activity

Physical activity has been identified as a modifiable lifestyle factor that could help prevent some of the complications and risks to pregnant women with overweight and obesity as mentioned in section 1.3. Physical activity improves glucose tolerance and insulin sensitivity in non-pregnant individuals, an effect that is maintained as long as regular activity is continued (DeFronzo, Sherwin, & Kraemer, 1987; Sigal, Kenny, Wasserman, & Castaneda-Sceppa, 2004). It is also known that increased exercise improves both insulin sensitivity and blood glucose levels in women with gestational diabetes (García-Patterson et al., 2001; Jovanovic-Peterson, Durak, & Peterson, 1989; Pivarnik et al., 2006); decreases back pain and optimises fetal and maternal well-being. There is expert consensus that physical activity before, and or during pregnancy improves long term offspring health. A recent meta-analysis reported that antenatal physical activity in women of any BMI led to a small reduction in offspring birth weight. It is possible that this modest reduction in birth weight in offspring of pregnant women with overweight and obesity may be beneficial in reducing long-term obesity risk in offspring (Pivarnik et al., 2006; Thangaratinam et al., 2012b).

Physical activity and exercise are concepts often used interchangeably in the literature. However, these terms actually describe different concepts. The WHO defines physical activity as 'any bodily movement produced by skeletal muscles that requires energy expenditure' (World Health Organisation, 2017). Physical activity in daily life can be categorised into occupational, sports, conditioning, household, or other activities (World Health Organisation, 2017). Exercise, then, is considered a subgroup of physical activity that is planned, structured, and recurring and is used to improve or maintain physical fitness. Therefore, exercise, is not identical to physical activity: it is a subcategory of physical activity (Caspersen, Powell, & Christenson, 1985). The WHO divides physical activity into intensity levels, such as 'moderate' and 'vigorous' physical activity. Intensity refers to the rate at which the activity is performed i.e. 'how hard the person works to do the activity' (Smith et al., 2017; World Health Organisation, 2017). Moderate intensity physical activity is described as 'activity that makes you breathe faster', requiring a moderate amount of effort and an increased heart rate (World Health Organisation, 2018). Furthermore, vigorous physical activity is described as causing rapid breathing, requiring a larger amount of effort and a substantial increase in heart rate (World Health Organisation, 2018).

1.5.1 Physical activity guidelines

Similar to Irish recommendations, current international guidelines recommend 30 minutes of daily moderate intensity physical activity for all pregnant women (HSE/ICGP, 2013; Society of Obstetricians and Gynaecologists of Canada, 2003; The Royal College of Obstetricians and Gynecologists, 2006). The UK guidelines state that 150 minutes of moderate physical activity spread throughout the week is appropriate for pregnancy (Smith et al., 2017). However, despite this, pregnancy is a period where women often decrease daily physical activity and participation in sports and exercise (Fell, Joseph, Armson, & Dodds, 2009).

1.5.2 Physical activity trends

Previous studies, carried out in different countries, have reported low percentages of physical activity during pregnancy. In the United States, only 15.8% of pregnant women ages 18-44 vs. 26.1% of non-pregnant women engaged in recommended physical activity (Evenson, Savitz, & Huston, 2004). Ning et al. 2013, reported that 23% of previously active women ceased to engage in exercise completely during pregnancy (Ning et al., 2003). In Brazil, only 4.7% of pregnant women were physically active

(Domingues & Barros, 2007). Furthermore, in Ireland, 21.5% of 358 healthy pregnant women between 10–24 weeks of gestation met the physical activity recommendations (Walsh, McGowan, Byrne, & McAuliffe, 2011). A study examining lifestyle changes using the Pregnancy Risk Assessment Monitoring System (PRAMS), Ireland found that adherence to physical activity guidelines of moderate intensity activity was low (12.3%) but was particularly low for pregnant women with a BMI>25kg/m² (6.4%)(O'Keeffe et al., 2016). These low rates of physical activity during pregnancy particularly for women with overweight and obesity are concerning given the significant health benefits for both mother and baby (Morris & Johnson, 2005).

1.5.3 Determinants of physical activity in pregnancy

Predictors of higher physical activity participation in pregnancy include higher education level, income, not having children in the home, being of white ethnicity and being more active before becoming pregnant (Gaston & Cramp, 2011). Other factors that might influence the level of physical activity during pregnancy are, for instance, early pregnancy symptoms, such as nausea and fatigue or the perception that physical activity during pregnancy is risky to maternal or foetal health (Fell et al., 2009).

1.6 Understanding and changing physical activity behaviour

Health psychology offers theories of behaviour that can be used for conceptualising complex behaviour change interventions, in both planning interventions and evaluating outcomes. Furthermore, the theory provides a framework to help test hypothesis, accumulate evidence, identify factors that influence behaviour and suggest techniques that should be incorporated in behaviour change interventions (Prestwich, Webb, & Conner, 2015). The most prominent theories used in physical activity research include The Social Cognitive Theory, The Theory of Planned Behaviour and The Transtheoretical Model (Nigg, Borrelli, Maddock, & Dishman, 2008). These theories have been used to explain and predict health behaviours.

1.6.1 The social cognitive theory

The social cognitive theory is based on the concept of reciprocal determinism or that a person's behaviour influences and is influenced by personal factors and the social environment (Bandura, 2004). Self-efficacy is considered the main construct within the social cognitive theory and it is defined as belief in one’s capability to accomplish a certain level of performance (Bandura, 1986). Self-efficacy has been utilised in a variety of health and physical activity contexts, including weight loss (McAuley, Blissmer, Katula, & Duncan, 2000; McAuley, Blissmer, Katula, Duncan, & Mihalko, 2000), exercise in older adults (Dallow & Anderson, 2003), exercise in adolescent girls (Dishman et al., 2004) and women's attitudes and intentions concerning physical activity (Chasan-Taber et al., 2009; Hausenblas et al., 2008; O'Toole, Sawicki, & Artal, 2003). For example, the use of a multimedia intervention for exercise during pregnancy showed a significant increase in self-efficacy and knowledge of the benefits of physical activity (Hausenblas et al., 2008). Other studies have suggested that perceptions of self-efficacy are important in terms of perceived benefits and risk for physical activity (Cramp & Bray, 2009, 2011).

1.6.2 The theory of planned behaviour

The theory of planned behaviour has been used to understand the influencing factors of adoption, motivation and adherence to physical activity (Ajzen & Fishbein, 1980). This theory was built on The Theory of Reasoned Action (Ajzen, 1991) to include the concept of perceived behavioural control. Perceived behavioural control is described as a person's belief that they have control over their own behaviour in certain situations (Morrison & Bennett, 2009). This theory hypothesises that people will intend to engage in a behaviour if they view it positively (attitude), believe that others want them to participate in certain behaviours (subjective norm), and perceive that the behaviour is under their control (perceived behavioural control). The theory of planned behaviour has been utilised in some physical activity studies: to examine children's physical activity intentions and behaviours (Hagger, Chatzisarantis, Biddle, & Orbell, 2001) and to examine physical activity among individuals with chronic diseases (Eng & Martin Ginis, 2007). Furthermore, the theory of planned behaviour has not only been used for physical activity but also for health behaviours including diet and weight control (Armitage & Conner, 2001; Conner, Norman, & Bell, 2002; McConnon et al., 2012; McEachan, Conner, Taylor, & Lawton, 2011).

1.6.3 The transtheoretical model

The transtheoretical model is an integrative, biopsychosocial model using a stage based approach. It was developed in an attempt to overcome some of the limitations of the social cognitive models (Prochaska & DiClemente, 1994). The model seeks to include and incorporate key constructs from other theories into a comprehensive theory of change that can be applied to a variety of behaviours, populations, and settings (Prochaska &

DiClemente, 1994). The transtheoretical model is a cyclical process whereby individuals pass through a number of stages towards effective and maintained behaviour change. The stages of change include pre-contemplation, contemplation, preparation, action and maintenance (Buchan, Ollis, Thomas, & Baker, 2012). Studies that have applied the transtheoretical model to physical activity have revealed that self-efficacy was increased among adults, with individuals in the action and maintenance stages recognising the benefits to physical activity than individuals who were sedentary (Marcus, Eaton, Rossi, & Harlow, 1994; Marcus & Owen, 1992; Marcus, Pinto, Simkin, Audrain, & Taylor, 1994). Furthermore, in pregnancy research, the participants classified as inactive showed a high motivational readiness or intention to increase their physical activity level (Hagen Haakstad, Voldner, & Bø, 2013).

1.6.4 Using theory to design interventions

Although many theories of behaviour exist, there is a lack of theory-based research across health-related fields to date, making it difficult or impossible to know what mechanisms underlie behaviour or behaviour change (Craig et al., 2008; Michie & Prestwich, 2010; Michie, van Stralen, & West, 2011c). As mentioned previously, antenatal lifestyle interventions often ignore or fail to report these mechanisms and theories, thus making it difficult to understand the key transferable intervention components (Asbee et al., 2009). These mechanisms of change are needed to provide explanations regarding the processes which are occurring, and to facilitate an understanding of complex situations (Davidoff, Dixon-Woods, Leviton, & Michie, 2015).

Evidence suggests that using theory to inform the development of interventions is associated with larger effect (Glanz & Bishop, 2010; Taylor, Conner, & Lawton, 2012). According to Michie and Prestwich (2010), basing interventions on theory can influence intervention effectiveness through enabling the appropriate selection of behaviour change techniques (BCTs) or a combination of these techniques (Prestwich et al., 2014). Furthermore, intervention effectiveness can be increased by including participants in the study who are likely to benefit from the intervention and tailoring BCTs to suit those individuals (Prestwich et al., 2014). A BCT is defined as ‘an active component of an intervention designed to change behaviour’ (Michie et al., 2013). In order to identify intervention content or behaviour change components of an intervention, the BCT taxonomy V1 was developed (Michie et al., 2013). This validated taxonomy consists of 93 different behaviour change techniques divided into 16 categories. A number of specific behaviour change techniques effect behaviours including physical activity, diet, alcohol consumption and medication use (Abraham & Michie, 2008; Michie et al., 2011b; Michie et al., 2012).

A meta-analysis of 122 diet and physical activity interventions for adults identified particularly effective behaviour change techniques which were, self-monitoring of behaviour as well as prompting specific goal setting and providing feedback on performance (Michie, Abraham, Whittington, McAteer, & Gupta, 2009). Moreover, a systematic review which evaluated the content of physical activity interventions, found that incorporating behaviour change techniques such as goals, planning and feedback could help reduce the decline in physical activity throughout pregnancy for healthy pregnant women (Currie et al., 2013). Therefore, the use of theories, and explicit description of their use, is necessary to facilitate the design of interventions to change behaviour (Craig et al., 2008; Davidoff et al., 2015).

1.7 Behaviour change

While there are a number of theories to choose from in order to change behaviour, in recent years, tools such as the Theoretical Domains Framework (TDF), and the Behaviour Change Wheel have become increasingly popular choices as theoretical frameworks to guide intervention development for researchers (Michie, Atkins, & West, 2014a).

1.7.1 Theoretical domains framework and the COM-B-model

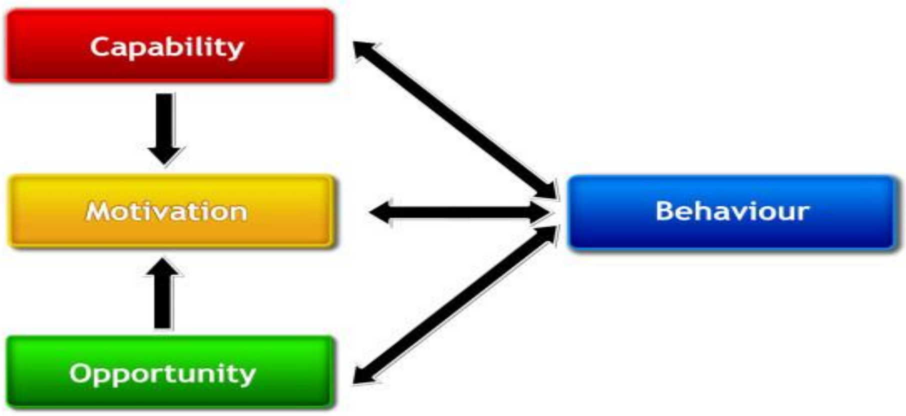
A framework was developed, derived from 33 commonly used behavioural theories and 128 psychological constructs called the theoretical domains framework. The theoretical domains framework has been identified as a useful tool for identifying determinants of behaviour and barriers to behaviour change. The framework consists of 14 domains: knowledge; skills; memory, attention and decision processes; behavioural regulation; social/professional role and identity; beliefs about capability; optimism; belief about consequences; intentions; goals; reinforcement; emotion; environmental context and resources and social influences (Table 2)(Michie et al., 2014a).

Table 2: Theoretical domains and definitions

Theoretical domains	Definition
Knowledge	Awareness of the existence of something: knowledge of condition
Skills	An ability or proficiency acquired through practice
Memory, attention and decision processes	The ability to retain information, focus selectively on aspect of the environment and choose between two or more alternatives
Behavioural regulation	Managing or changes action – self-monitoring
Social/professional role and identity	Set of behaviours and displayed personal qualities in a social or work setting
Beliefs about capability	Acceptance of the truth, reality or validity about an ability, perceived behavioural control, self-esteem, confidence
Optimism	The confidence that things will happen for the best or that desired goals will be attained
Beliefs about consequences	Acceptance of the truth, reality or validity about outcomes of a behaviour in a given situation
Intentions	A conscious decision to perform a behaviour or a resolve to act in a certain way
Goals	Mental representations of outcome or end states, that an individual wants to achieve
Reinforcement	Increasing the probability of a response by arranging a dependent relationship or contingency, between the response and a given stimulus
Emotion	A complex reaction pattern, involving experiential, behavioural and physiological elements by which the individual attempts to deal with a personally significant matter or event
Environmental context and resources	A persons situation or environment that encourages or discourages the development of skills and abilities, independence, social competence and adaptive behaviour
Social influences	Process that can change thoughts, feelings, or behaviours – social pressure

(French et al., 2012; Michie et al., 2014a)

The theoretical domains framework has been used primarily in the context of health and to understand behaviour at an individual level (Alexander, Brijnath, & Mazza, 2014; Beenstock et al., 2012; Heslehurst et al., 2014), but it can also be used in different contexts, at an organisational and community level to understand behaviour (Michie et al., 2014a). Each domain of the theoretical domains framework relates to a component of the COM-B model which stands for “capability”, “opportunity”, “motivation” and “behaviour” (Michie et al., 2014a; Michie et al., 2011c). The COM-B model proposes that for any behaviour to occur a person must have the psychological and physical capability to perform the behaviour; the physical and social opportunity to engage in it and must be motivated to do so. Changing the occurrence of any behaviour involves identifying what needs to change regarding someone's "capability", "opportunity" and "motivation" to engage in that behaviour (Michie et al., 2014a). The COM-B components interlink so that, for example, increasing opportunity or capability can increase motivation (Michie et al., 2014a) (Figure 1).

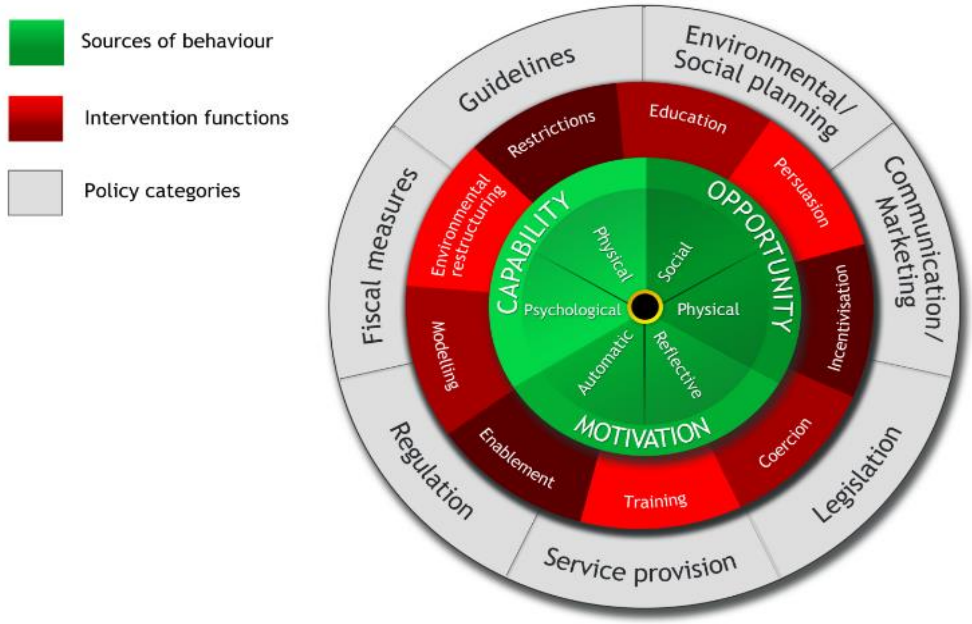


(Michie et al., 2014a)

Figure 1: The COM-B model

1.7.2 Behaviour change wheel

The COM-B model is the hub of the behaviour change wheel. The behaviour change wheel is a synthesis of 19 frameworks of behaviour change found in the literature (Michie et al., 2014a). It is an approach based on a comprehensive causal analysis of behaviour and starts by asking the question: 'what conditions within an individual's social and physical environment need to be in place for a specific behavioural target to be achieved' (Michie et al., 2011c). Also, the behaviour change wheel is a tool that can aid the design and development of interventions and polices based on the nature of the behaviour, the mechanisms that are needed in order to bring about behaviour change and the interventions needed to bring about this change (Michie et al., 2011c). At the centre of the behaviour change wheel is the COM-B model, around which are nine interventions functions to address the target behaviour and seven policy categories to enable the interventions (Michie et al., 2014a) (Figure 2).



(Michie et al., 2014a)

Figure 2: Behaviour change wheel for designing complex behaviour change intervention

1.8 Summary

Despite the wide-ranging health benefits of physical activity, low rates of physical activity in pregnancy are still evident, demonstrating the need to include physical activity promotion in antenatal interventions. It is essential to unravel how certain factors impact physical activity and to understand the barriers and enablers to physical activity for pregnant women with overweight and obesity, in order to develop effective interventions and policies.

Numerous antenatal interventions for gestational weight gain and gestational diabetes provide no clear indication of the intervention content, the preferred intervention setting, method of intervention delivery, or intervention focus to support pregnant women with overweight and obesity in their physical activity efforts. Moreover, the use of theories, explicit description of their use and description of the active ingredients within these interventions are lacking. This lack of research on effective intervention components within existing interventions highlights the need for pre-intervention research to inform the development of a theory and evidence based intervention programme to increase physical activity levels that will meet the needs and expectations of pregnant women with overweight and obesity.

1.9 Overall aim of this research

With current evidence suggesting that pregnancy is a time for excessive weight gain (Davis, Zyzanski, Olson, Stange, & Horwitz, 2009), promoting healthy weight gain and preventing excessive weight gain during pregnancy is becoming a key element in obesity prevention, offering unique opportunities for public health interventions. Physical activity during pregnancy is a core contributor to energy balance, potentially influencing weight and weight gain (Butte & King, 2005). Inactivity during pregnancy is cause for concern because prenatal women who do not engage in exercise forgo numerous health benefits such as those mentioned in section 1.5.

While most antenatal interventions tend to be multicomponent with a combination of physical activity and diet (Guelinckx et al., 2010) some argue that attempting to influence numerous behaviours simultaneously puts high demands on participants (de Vries et al., 2008) and prove less successful compared to targeting a single behaviour. Therefore, this body of work focuses on physical activity behaviour.

The overall aim of this PhD is to enhance our understanding of physical activity for women with overweight and obesity during pregnancy with the view to inform the development of a theoretically informed behaviour change intervention. This research employs recent tools in behavioural science: the Theoretical Domains Framework; the COM-B model; Behaviour Change Techniques and the Behaviour Change Wheel to better understand the barriers and enablers to physical activity for pregnant women with overweight and obesity. The results from this work will aid the development of a theory and evidence-based interventions to increase physical activity levels for this target population.

1.9.1 Research objectives and thesis outline

Study objectives are addressed in the form of four studies presented below (Figure 3).

Study 1: What factors impact physical activity levels during pregnancy?

C Flannery, D Dahly, M Byrne, AS Khashan, S McHugh, LC Kenny, FM McAuliffe, PM Kearney. **Social, biological, behavioural and psychological factors and physical activity during pregnancy: a cross-sectional study** (BMJ Open – Awaiting editorial decision 31st Aug 2018)

Study 2: What are the enablers and barriers to physical activity for pregnant women with overweight and obesity?

C Flannery, S McHugh, AE Anaba, E Clifford, M O'Riordan, LC Kenny, FM McAuliffe, PM Kearney, M Byrne. **Enablers and barriers to physical activity in overweight and obese pregnant women: an analysis informed by the theoretical domains framework and COM-B model.** BMC Pregnancy Childbirth. 2018;18(1):178.

Study 3: What approach do midwives, obstetricians and general practitioners take when providing antenatal care for women with overweight and obesity during pregnancy?

C Flannery, S McHugh, L Kenny, MN O'Riordan, FM McAuliffe, C Bradley, PM Kearney, M Byrne. **Exploring obstetricians, midwives and general practitioners approach to weight management in pregnant women with a BMI ≥25: a qualitative study** (BMJ Open – Revise and resubmit recommended, resubmission due 20th Oct 2018)

Study 4: Are physical activity interventions for pregnant women with overweight and obesity effective at increasing/improving physical activity levels and what behaviour change techniques are used within these interventions?

C Flannery, M Fredrix, E Olander, FM McAuliffe, M Byrne, PM Kearney. **Physical activity interventions for overweight and obesity during pregnancy: A systematic review of the effectiveness and content of behaviour change interventions** (Obesity Reviews – Revised and resubmitted 21st Sept 2018)

The methodologies used to conduct these studies are outlined in detail in the next chapter. The four studies are included in chapter’s three to five. A general discussion of the overall findings of the four studies, the limitations of this research and implications for future research and practice are presented in the final chapter of this thesis.

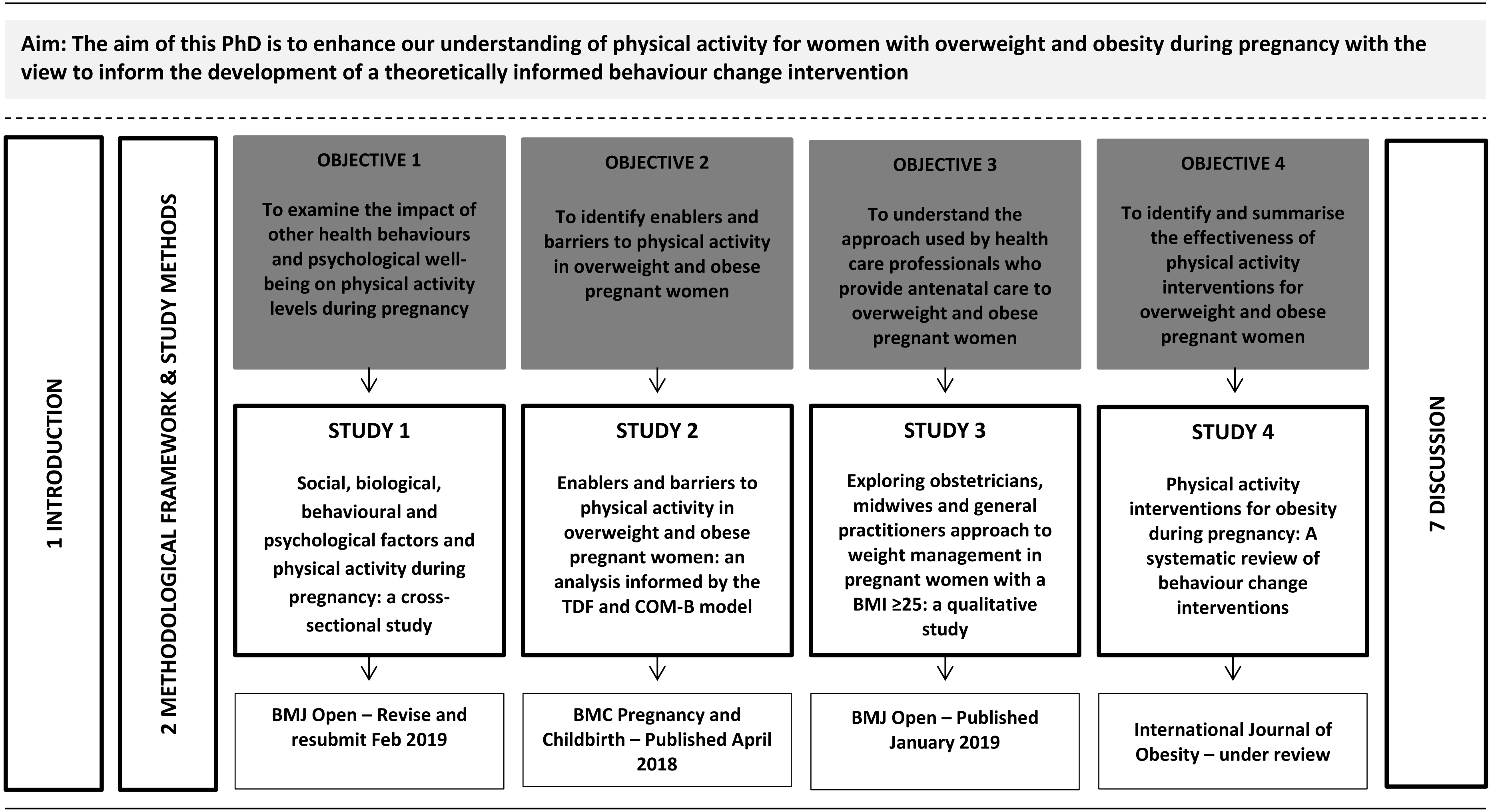


Figure 3: Thesis outline

2 METHODOLOGICAL FRAMEWORK AND STUDY METHODS

2.1 Overview

The aim of this chapter is to outline the overall design of this research. It provides a description of the UK Medical Research Council framework for developing complex interventions and the behaviour change wheel. An overview of the methods used to address the aims and objectives of this research is provided here. Finally, the ethical issues associated with in this study will also be addressed.

2.2 Aims and objective of this research

The primary aim of this research is to enhance our understanding of physical activity during pregnancy. Quantitative and qualitative research methods were used with the view to inform the development of a theory and evidence based intervention to increase physical activity levels for pregnant women with overweight and obesity.

2.3 Overview of study design

A concurrent mixed methods design was used in this research, utilising different research approaches while also following phase one of the Medical Research Council Framework for developing complex interventions (Creswell & Clark, 2017). The development phase of the Medical Research Council Framework includes identifying the evidence-base, identifying or developing a theory, and modelling processes and outcomes. This involves identifying what is already known about similar interventions and the methods that have been used to evaluate them. Quantitative research methods such as systematic reviews and meta-analyses are used to achieve this aim. These methods can provide insight into the intervention components that have potential to be effective but does not offer guidance about which components are crucial or how best to implement them (Yardley, Morrison, Bradbury, & Muller, 2015). Qualitative research with key stakeholders can provide a deeper understanding of these needs (Yardley et al., 2015). For these reasons, both types of research methodologies were used in order to understand physical activity during pregnancy for pregnant women with overweight and obesity. An overview of the study design is presented in Figure 4.

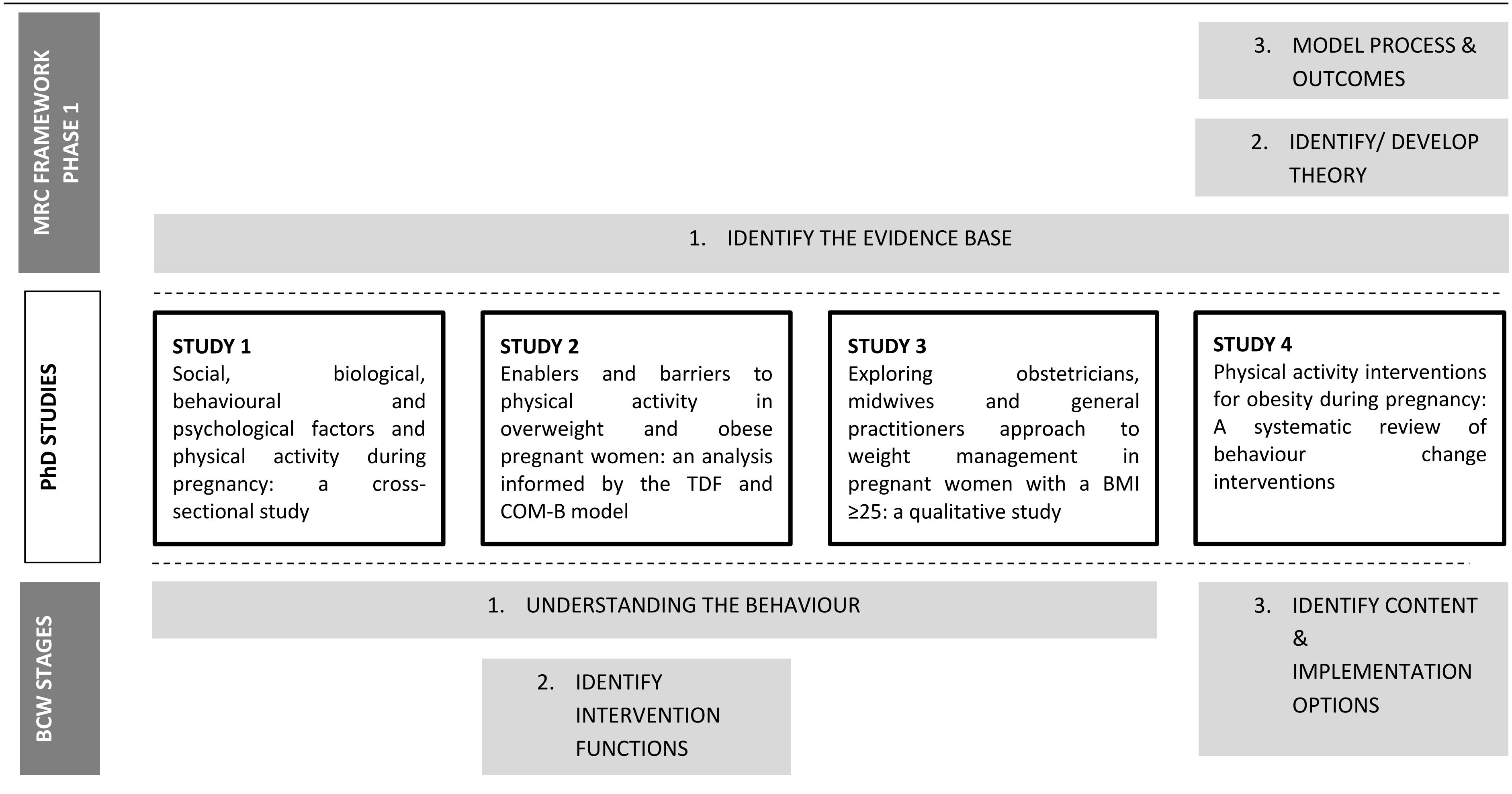
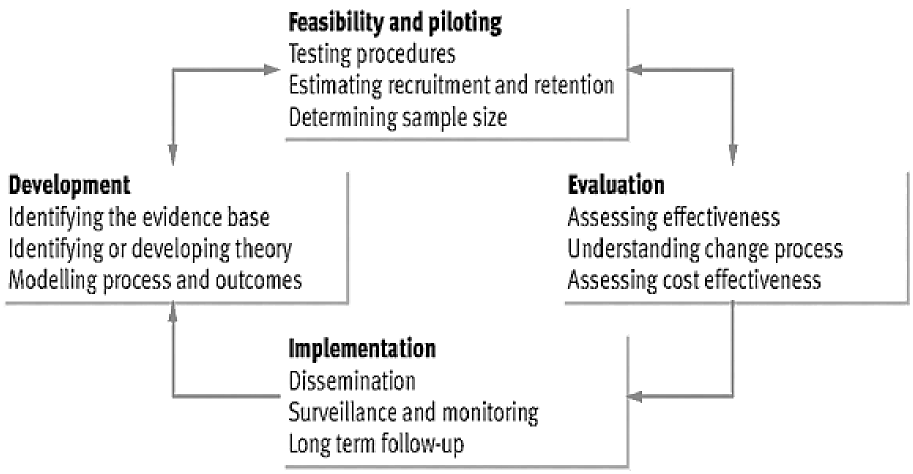


Figure 4: PhD studies mapped to the medical research council framework and the behaviour change wheel

2.4 The medical research council framework

The Medical Research Council (MRC) framework for developing complex interventions is a tool used to develop, evaluate and implement a complex intervention to improve health (Medical Reseach Council, 2008). The MRC framework summarises the main stages and the key functions and activities at each stage. It states that to develop an intervention you must use the best available evidence and appropriate theory, followed by testing the intervention with a serious of pilot studies and then move on to a definitive evaluation. These phases do not automatically occur in a linear order, but the framework can help researchers define where they are in the research process. Detailed description of the intervention facilitates better replication, evidence synthesis and implementation. Due to the poor quality and unclear results from existing interventions (as described by the literature, chapter 1) there is a need for pre-intervention research to inform the development of an intervention that will increase physical activity levels for pregnant women with overweight and obesity. Therefore, this PhD thesis will focus on the 'Development' phase 1 of the MRC framework (Figure 5).



(Medical Reseach Council, 2008)

Figure 5: Medical research council framework for developing complex interventions

2.5 Identifying the evidence base

2.5.1 New evidence

The existing evidence on physical activity in pregnancy was supplemented with new evidence created by three studies detailed below:

1. Study 1: Social, biological, behavioural and psychological factors and physical activity during pregnancy: a cross-sectional study.

Physical activity during pregnancy is associated with a number of health benefits, despite this; women reduce physical activity during pregnancy. Therefore, secondary analysis of data from a prospective cohort study, the Screening for pregnancy endpoints (SCOPE) was conducted. The aim of this study was to identify the social, biological, behavioural and psychological factors related to physical activity in early pregnancy.

SCOPE is an international, multicentre cohort study. Nulliparous women with singleton pregnancies were recruited and then interviewed at 15±1 weeks' gestation from a SCOPE Centre, Cork University Maternity Hospital, Ireland. The bio-psychosocial model identified factors including: social factors (age, marital status, ethnicity, accommodation and socioeconomic index), biological (BMI and gravidity), behavioural (diet, alcohol and smoking) and psychological factors (anxiety, stress and depression) at 15±1 weeks' gestation. This bio-psychosocial model recognises the influences of the biological, psychological, and social dimensions of a person's life (Engel, 1981). Participants were asked in three separate questions how often they engaged in vigorous exercise *(exercise which made you breathe harder or pant)*, moderate exercise *(exercise which did not make you breathe harder or pant)*, and recreational walking *(walking for recreation or exercise)*. Responses to each of the three questions were self-reported and coded as *never; once a week; 2-3 times a week; 4-6 times a week; daily; more than twice daily*. Physical activity subgroups were identified based on a latent class analysis of participant's responses to these physical activity survey items.

Latent class analysis is a statistical method for finding unobservable subgroups within a population (Hagenaars & McCutcheon, 2002; Lanza, Tan, & Bray, 2013; McCutcheon, 2002). It is set up in the belief that ''two or more underlying subgroups in a population, and subgroup membership can be inferred from responses to multiple items'' (McCutcheon, 2002). Each of the classes identified are composed of individuals who report similar responses to a set of observed variables (Lanza & Rhoades, 2013; Lanza et al., 2013). In this study latent class analysis was used to identify mutually exclusive subgroups based on these three physical activity categorical survey items using Mplus Version 6. The central challenge to any latent class model is to select the appropriate number of classes (or subgroups), which must be set. To do this, a series of models were estimated where the number of latent classes ranged from 1 to 6. The authors then met to discuss the results and a final number of latent classes were selected based on model fit statistics (using Akaike information criterion (AIC) and Bayesian information criterion (BIC)), parsimony, theoretical interpretability, and classification quality. Once the final model was chosen, participants were assigned to their most likely class (i.e. their modal assignment).

Secondary analysis was performed using Stata (Version 13). Associations between participant characteristics and the physical activity subgroups identified in the latent class analysis were explored using chi-squared test for categorical and ANOVA for continuous variables. Unadjusted multinomial logistic regression was conducted to examine the association between covariates and physical activity level. Furthermore, multivariable, multinomial logistic regression was conducted using a hierarchical approach (Victora, Huttly, Fuchs, & Olinto, 1997) whereby model 1 included the social factors, model 2 added the biological factors, and model 3 was further adjusted for the behavioural and psychological factors. All variables are included in the adjusted model. Regression analysis is a statistical technique for investigating the relationship between variables. The multinomial logistic regression model is a simple extension of the binomial logistic regression model (Bayaga, 2010). It is used here because the dependent variable 'physical activity subgroups' has more than two nominal or unordered categories. Estimated coefficients are reported as Relative Risk Ratios (RRR) with 95% confidence intervals (CI) using those who reported low physical activity levels as the reference category. RRR is used because the exponentiated coefficient in multinomial logistic regression is the ratio of two relative risks (RRR) and is not to be confused or interpreted as an odds ratio (OR).

Reliability and validity are two important and fundamental features in the evaluation of any measurement instrument (Mohajan, 2018). For secondary data, a detailed assessment of reliability and validity involves an appraisal of methods used to collect data (Saunders, Lewis, & Thornhill, 2009). Without assessing reliability and validity of the research, it will be difficult to describe the effects of measurement error on theoretical relationships that are being measured (Forza, 2002).

To ensure the reliability and validity of the SCOPE data used in Study 1, obtaining detailed descriptions of the population, sampling scheme and strategy, time frame of data collection, assessment tools and response levels was essential. Study detail, questionnaires and data codebooks were obtained prior to commencing the secondary data analysis (Appendix A). These documents provide sufficient information to assess the internal and external validity of the data and allow researchers to determine whether or not there are enough in the dataset to generate estimates about the topic of interest (Cheng & Phillips, 2014). For this analysis, a research question driven approach was used and it was therefore essential to consider the statistical analysis plan (sample size, variables, correlation, variance, standard error, statistical significance of the model used in the analysis, reproducibility of results, etc.). Most of the data on maternal lifestyle factors were based on self-report and are likely measured with error particularly the dietary and physical activity variables. These items were based on questions about the consumption of selected food items and how many times a week they engaged in exercise that did not result in heavier breathing rather than more established methods for dietary assessment and physical activity measurement. Furthermore, while the cognitive, behavioural and emotional factors were collected using validated scales; these measures use self-report rather than clinical diagnosis.

2. **Study 2: Enablers and barriers to physical activity in overweight and obese pregnant women: an analysis informed by the TDF and COM-B model.**

Using the theoretical domains framework and COM-B model, this study aimed to identify the enablers and barriers to physical activity in pregnant women with overweight and obesity.

Medical chart review identified a convenience sample of women with overweight and obesity at different stages of pregnancy attending a public antenatal clinic in a large academic maternity hospital, Cork University Maternity Hospital, Ireland. Interviews were recorded and transcribed into NVivo V.10 software. Eligible participants were approached individually and informed about the study by the attending midwife and researcher on site at their antenatal appointment. Recruitment took place at the Diabetes clinics, where they were also provided with an information leaflet explaining the purpose of the study. Face-to-face interviews using a semi-structured interview schedule were carried out in the antenatal clinic on a day and time suitable for the participant.

Data analysis followed a framework approach (Gale, Heath, Cameron, Rashid, & Redwood, 2013). An inductive thematic analysis was conducted to identify new emerging themes and to investigate a priori objectives using the theoretical domains framework and COM-B model. Each transcript was read and re-read numerous times, coded line by line and analysed to identify similarities and differences. Following open-coding, broader categories were mapped onto the domains of the theoretical domains framework and then, directly onto the six components of the COM-B model thus identifying emerging themes relating to enablers and barriers to physical activity for pregnant women with overweight and obesity.

3. **Study 3: Exploring obstetricians, midwives and general practitioners approach to weight management in overweight and obese pregnancy women.**

In Ireland, antenatal care is shared between hospital based health care professionals (HCPs) (such as midwives and obstetricians) and general practitioners (GPs) (Hanafin & Dwan O'Reilly, 2016). While these HCPs have been identified as vital contributors to the antenatal services, little is known about the ways in which such professionals engage with pregnant women with overweight and obesity (Widen & Siega-Riz, 2010). Therefore, the aim of this study was to understand the approach taken by midwives, obstetricians and GPs who provide antenatal care to pregnant women with a BMI ≥25kg/m^2.

A convenience sample of hospital based HCPs were identified at Grand Rounds from a public antenatal clinic at Cork University Maternity Hospital, Ireland. These hospital based HCPs included midwives and consultant obstetricians who provide care for women either during pregnancy, labour and birth, or in the postnatal period. GPs in the Cork-Kerry region were identified using a GP list provided by the Department of General Practice at University College Cork, which included GP names and contact details. GPs were a convenience sample based on gender and location of practice (urban/rural). GPs were recruited from single or group practices serving both public and private patients HCPs and GPs were provided with an invitation letter and study information sheet.

Face-to-face semi-structured interviews using a topic guide were carried out at the hospital antenatal clinic or in the primary care setting. Written informed consent was obtained from all HCPs and GPs prior to the interview. Interviews were audio recorded and transcribed verbatim. NVivo V.10 software was used to facilitate data analysis. Thematic analysis as described by Braun and Clarke, 2006 was used to analyse the data (Braun & Clarke, 2006). An inductive approach was used, allowing themes to be developed in a data-driven, 'bottom up' way (Braun & Clarke, 2006). Transcripts were read and open-coded. These codes were grouped according to HCPs beliefs and attitudes, how they approach weight management and the reasons for this approach. Codes, and categories where discussed and sub-themes were synthesised and organised to develop broader themes.

2.5.2 Existing evidence

The existing evidence on physical activity interventions for pregnant women with overweight and obesity was examined by a systematic review and meta-analysis as detailed below:

4. **Study 4: Physical activity interventions for overweight and obesity during pregnancy: A systematic review of behaviour change interventions.**

As stated by the MRC framework, complex interventions should be developed systematically using the best available evidence (Medical Reseach Council, 2008). Therefore, the existing evidence-base on physical activity interventions for pregnant women with overweight and obesity and the BCTs employed in these interventions was systematically reviewed using meta-analysis and narrative descriptions. The review protocol was pre-registered with the International Prospective Register of Systematic Reviews (PROSPERO) database (CRD42016033423) (Appendix C).

An explicit and systematic process was used to obtain all relevant published literature, to evaluate the quality of the evidence and to produce a comprehensive and reliable synthesis of the evidence (Garg, Hackam, & Tonelli, 2008). This systematic review and meta-analysis were conducted and reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Moher, Liberati, Tetzlaff, & Altman, 2009). Eligible study designs included pilot randomised controlled trials, randomised control trials (RCTs), non-randomised control trials, quasi RCTs, and quasi-experimental studies of physical activity interventions aimed at maintaining or increasing physical activity levels conducted either in a health care setting, community setting, online, or at the individual's home. Furthermore, for inclusion, all interventions had to target pregnant women with overweight and obesity with a pre-pregnancy or early pregnancy BMI ≥25kg/m^2 and singleton pregnancies, have at least one component focusing explicitly on physical activity (subjectively or objectively measured) and include a discernible BCT in the intervention description.

MEDLINE, EMBASE, PsychInfo, CINAHL, Cochrane Library, PEDro, SportDiscus and PubMed databases were searched from inception. The searches were undertaken in June 2016 and a second search, updating the literature was conducted in January 2018**.** In the first screening stage, all titles of the search results were examined and irrelevant titles were removed if they did not meet the inclusion criteria. In the second stage, title and abstracts were screened. Cohen's kappa (*k)* was calculated to determine the extent of interrater agreement (Cohen, 1960; Landis & Koch, 1977). In the third stage of the screening process, relevant articles were obtained in full and assessed against the inclusion and study quality criteria. Full text screening was conducted.

A data form was developed based on the Workgroup for Intervention Development and Evaluation Research (WIDER) framework for the scientific reporting of behaviour change interventions (Albrecht, Archibald, Arseneau, & Scott, 2013). Data from each included study were extracted by one reviewer and independently checked by two others. In the case of discrepancies, consensus was reached through discussion. Extracted data included detailed description of the interventions and BCTs included in the intervention. Physical activity measures for pre and post intervention, where possible, were extracted from studies or calculated using reported means, standard deviations, and sample sizes at baseline, post-intervention.

The BCT taxonomy V1 (Michie et al., 2013) was used to identify the behavioural components of the intervention within each included study. The BCT coding was completed independently by two reviewers who underwent training in BCT coding using the BCT taxonomy. The validity of each included study was assessed using the Cochrane

Collaboration's tool for assessing risk of bias (Green, 2011). This tool assesses key methodological domains; sequence generation, allocation concealment, blinding of participants, personnel and outcome assessors, incomplete outcome data, selective outcome reporting, other sources of bias (Green, 2011). The risk of bias was assessed by one reviewer and in the case of discrepancies; consensus was reached through discussion with two co-authors.

Continuous data were summarized as mean difference and standard deviations. Where possible, means and standard deviations were calculated from median and interquartile range (Hozo, Djulbegovic, & Hozo, 2005). Within the meta-analysis, physical activity outcomes reported on the same scale were combined using standardised mean differences. For all effect sizes, 95% Confidence intervals were used and results were pooled using a random effects model (inverse-variance approach based on weighted standardised mean differences) using RevMan Software (version 5.3: Review Manger). Furthermore, the I^2 statistic was used to indicate the percentage of total variation (Green, 2011). The remaining physical activity outcome measures were combined in a narrative synthesis as meta-analysis was not possible, due to the different physical activity outcomes within the studies. The narrative synthesis describes these studies, using words and text to summarise and explain the findings of the individual studies (Popay et al., 2006). A BCT was only coded when there was clear evidence of its inclusion in the intervention and it was identified as present by both reviewers. The total number of BCTs was recorded and the frequency of identified BCTs was quantified.

2.6 Identifying theory and modelling process and outcomes

Within the MRC framework the third step of modelling processes and outcomes has been insufficiently described in previous research in comparison to step one (identifying the evidence base) or two (identifying or developing theory). The purpose of modelling in previous studies has been to develop an understanding of a proposed intervention and its possible effects (Paul, Smith, Whitford, O'Kelly, & O'Dowd, 2007; Sinnott et al., 2015) with the overall aim of maximising the chances of a successful trial that will add to knowledge and improve outcomes (Rowlands, Sims, & Kerry, 2005).

Developing an intervention using robust knowledge and theory can increase its success in improving clinical outcomes. A review identified that interventions that incorporate theory are more likely to be successful (Davidoff et al., 2015; Glanz & Bishop, 2010). Two components have been identified: intervention programme (employed BCTs) and intervention delivery (intervention provider, format, setting, recipient, intensity, duration and fidelity of the intervention) (Collins, Murphy, Nair, & Strecher, 2005). Applying theory to the design and evaluation of complex interventions involving behaviour change is essential and can result in large interventions effects (Prestwich et al., 2014).

In future research, the MRC framework, the Behaviour Change Wheel and related models will be explicitly used to integrate behavioural theory with results from studies 1-4 in this PhD to develop a complex intervention to increase physical activity levels for pregnant women with overweight and obesity. The model of behaviour at the core of the Behaviour Change Wheel, the COM-B model used in study 2 will guide the choice of intervention strategies most likely to achieve behaviour change and emphasis the behaviour change techniques particularly suitable for these intervention strategies. Following this structured approach lends transparency to the process of intervention development (Michie et al., 2011c). The application of these models to this PhD data will be described in future work. This future work will determine the most appropriate intervention functions, effective BCTs and implementation plan most likely to affect physical activity behaviour.

2.7 Ethical considerations

As studies 2 and 3 involved qualitative data collection, securely managing the data was of particular importance. The interviews were digitally recorded and the data was saved to a password protected computer. Participants were pseudonymised during transcription, and these transcripts were stored in a secured location. Informed consent was obtained from all participants prior to the interview to ensure that the research was in line with the individuals' values and it was truly the decision of the individual to take part in the research (World Medical Association, 2013).

2.8 Reflexivity Statement

As the researcher, I was aware of the importance of my own presence in the research process (Barry, Britten, Barber, Bradley, & Stevenson, 1999). Within the context of this work, I conducted face-to-face interviews with both pregnant women with overweight and obesity and with HCP (including midwives, obstetricians and GPs) and therefore needed to consider the ways in which my interactions with these participants might be influenced by my background, experiences and prior beliefs.

As an academic PhD researcher with a non-clinical background, I considered whether or not knowing about my background would impact participants and their willingness to talk openly about their experiences. Prior to the interviews with the pregnant women I made a conscious effort to build rapport, chatting informally about the research, the interview process and my background as a researcher. I was also sensitive to the fact that, I, myself, have no lived experience of pregnancy and how this might impact participant's responses. At the beginning of interviews with HCPs, I highlighted that I was not medically qualified, allowing them to discuss pregnancy and common medical issues in detail. I also kept in mind their professional status and busy schedules, making the best use of time available. I believe my lack of personal and medical experience of pregnancy allowed them to speak freely and reflect on their experiences.

All interviews for both pregnant women and HCPs were face-to-face and took place in the maternity hospital, antenatal clinic or in a primary care setting. I made every effort to ensure each participant was comfortable and the setting was suitable. As the research participant's varied two different topic guides were designed to keep participants engaged in the research, using simple language for questions, prompts and probes. My co-authors (with backgrounds in public health, psychology and obstetrics and gynaecology) and I (for both qualitative studies - study 2 and study 3) worked closely together on all aspects of data collection, analysis, interpretation and write up. Analysis of these interviews included a process of constant comparison, to uncover similarities and differences with the main goal of identifying emerging themes. I met frequently with my second coders to discuss the interviews and to reflect on the data collection and analysis. Extensive field notes including observations about the participant, the setting, my own personal notes, coding and theoretical development were discussed at regular team meetings.

2.9 Summary

This chapter provided an overview of the study design and details of the methodological approach of each study. The use of different methodologies in this PhD is demonstrated by the four different studies. The aim of the four studies described in this chapter was to address phase one of the MRC framework for developing complex interventions. The following chapters will describe the individual studies conducted as part of this PhD research.

3 STUDY 1: PHYSICAL ACTIVITY DURING PREGNANCY

Social, biological, behavioural and psychological factors and physical activity during pregnancy: a cross-sectional study

C Flannery, D Dahly, M Byrne, AS Khashan, S McHugh, LC Kenny, FM McAuliffe, PM Kearney

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3.1 Abstract

Background: To identify the social, biological, behavioural and psychological factors related to physical activity in early pregnancy.

Methods: Secondary analysis of data from a prospective cohort study in Cork, Ireland. Nulliparous women with singleton pregnancies were recruited and then interviewed at 15±1 weeks' gestation. The bio-psychosocial model identified factors including: social (age), biological (body mass index), behavioural (diet) and psychological (anxiety) at 15±1 weeks' gestation. Physical activity subgroups were identified based on a latent class analysis of their responses to a set of questions about the amount and intensity of activity they were engaging in during the pregnancy. Associations were estimated with multivariable multinomial logistic regression models.

Results: From a total of 2579, 1774 (69%) women were recruited; ages ranged from 17-45 years. Physical activity subgroups identified: *low* physical activity (n = 393); *moderate* physical activity (n = 960); and *high* physical activity (n = 413). The fully adjusted model suggests, Caucasian, non-smokers, and consumers of fruit and veg were associated with high physical activity (vs. low). Having >12 years of schooling and a higher socioeconomic status (≥24) was related to moderate physical activity (vs. low).

Conclusion: The findings highlight some key un-modifiable links that should guide the development of interventions, using a population approach, in order to encourage pregnant women to engage in physical activity.

3.2 Introduction

The World Health Organisation (WHO) defines physical activity as ‘any bodily movement produced by skeletal muscles that requires energy expenditure’ including leisure time physical activity, walking, household chores, games, sports or planned exercise, in the context of daily, family, and community activities (World Health Organisation, 2017). Regular physical activity during pregnancy is beneficial for both mother and fetus as it helps to prevent complications, limit weight gain, and decrease the risk of gestational diabetes; while fetal benefits include decreased fat mass and improved stress tolerance (Melzer, Schutz, Boulvain, & Kayser, 2010). Despite the significant health benefits, physical activity is lower among pregnant woman than non-pregnant women (Evenson & Wen, 2010; Walsh et al., 2011).

Healthy women with uncomplicated pregnancies are currently advised to continue pre-pregnancy exercise activities, or begin a program of regular activity (American College of Obstetricians Gynecologists, 2003; Davies, Wolfe, Mottola, & MacKinnon, 2003). The American Congress of Obstetricians and Gynaecologists (ACOG) recommend, in the absence of either medical or obstetric conditions, 30 minutes or more of daily moderate physical activity during pregnancy (Society of Obstetricians and Gynaecologists of Canada, 2003; The Royal College of Obstetricians and Gynecologists, 2006). Recommendations based on UK guidelines state that 150 minutes of moderate physical activity spread throughout the week is appropriate for pregnant women (Smith et al., 2017). Studies using self-report measures of physical activity in the UK and USA estimate that only 3–15% of pregnant women meet current guidelines, compared to 24–26% of non-pregnant women (Borodulin, Evenson, & Herring, 2009; Evenson & Wen, 2011). In Ireland, only one-fifth of pregnant women meet physical activity guidelines, and over 10% of pregnant women report no physical activity (Walsh et al., 2011).

Developing an active lifestyle throughout pregnancy can support fetal and maternal well-being and may also produce long term benefits (Melzer et al., 2010). Physical inactivity throughout pregnancy is a major challenge and there is a need for effective strategies to increase activity during pregnancy. Recognising and understanding the correlates of physical activity, as well explaining how these correlates influence subsequent behaviour is fundamental to intervention development and implementation.

Previous observational studies have found that demographic factors such as age, income and education are important correlates of participation in physical activity during pregnancy (Gaston & Cramp, 2011; Mottola & Campbell, 2003; Ning et al., 2003). Furthermore, factors such as BMI has been associated with both increased and decreased level of exercise during pregnancy compared to pre-pregnancy levels (Mottola & Campbell, 2003). Of women who engaged in a regular exercise regime, those most likely to quit by the 3rd trimester were women who had a high BMI and those who had gain more weight during pregnancy (Mottola & Campbell, 2003). Social factors like unemployment have been shown to influence physical activity levels (Gjestland, Bø, Owe, & Eberhard-Gran, 2012; Liu et al., 2011) with higher education, a higher income and not having children being predictors of high exercise participation (Gaston & Cramp, 2011). These studies have used various physical activity measures such as recreational activity, occupation or household activity as opposed to total physical activity. Therefore, a further understanding of physical activity level is essential in order to increase activity during pregnancy.

Using data from a prospective Irish cohort, this cross-sectional study aims to identify the different social, biological, behavioural and psychological factors that are linked with physical activity levels during pregnancy.

3.3 Methods

Study Design and population

Secondary analysis of the Irish data from the prospective cohort study Screening for Pregnancy End Points (SCOPE). Scope is multicentre cohort study (Cork, Auckland, Adelaide, London, Leeds, and Manchester) with the main aim of developing screening tests to predict pre-eclampsia, small for gestational age infants and spontaneous pre-term birth as previously described (McCowan, North, & Taylor, 2007; McCowan et al., 2009; North et al., 2011). In brief, healthy nulliparous women with singleton pregnancies were recruited and then interviewed at 15±1 weeks' gestation from Cork University Maternity Hospital, Ireland (n=1774) between March 2008 and February 2011 with the last baby born in August 2011. At 15±1 and 20± weeks' gestation comprehensive data were collected on social factors including age, marital status, ethnicity, accommodation, socioeconomic index; behavioural and psychological factors before conception and during pregnancy. Women were followed prospectively and research midwives collected data on pregnancy outcomes and measurements of the baby. For the purpose of this cross sectional study, only data collected at 15± is analysed.

Outcome measure

In three separate questions, participants were asked how often they engaged in vigorous exercise *(exercise which made you breathe harder or pant)*, moderate exercise *(exercise which did not make you breathe harder or pant)*, and recreational walking *(walking for recreation or exercise)*. Responses to each of the three questions were self-reported and coded as *never; once a week; 2-3 times a week; 4-6 times a week; daily; more than twice daily*. To create a physical activity level outcome the total number of cells from a cross-tabulation would be large and difficult to collapse into groups. Therefore, latent class analysis was used to identify mutually exclusive subgroups in the sample of participants based on these three categorical survey items (Hagenaars & McCutcheon, 2002). The central challenge to any latent class model is to select the appropriate number of classes (or subgroups) that best describe the observed set of responses. Because the number of latent class must be set by the user, we estimated a series of models where the number of latent classes ranged from 1 to 6. The authors then met to discuss the results and a final number of latent classes were selected based on model fit statistics (using Akaike information criterion (AIC) and Bayesian information criterion (BIC)), parsimony, theoretical interpretability, and classification quality. Once the final model was chosen, participants were assigned to their most likely class (i.e. their modal assignment).

Covariates

Social measures

Characteristics included: maternal age (*years or age category; <25 year, 25-29 years, 30-34 years, ≥35years*); ethnicity (*Caucasian vs. non-Caucasian*); relationship status (*single, married/partner*); employment status (*working vs. not working*); accommodation (*own home or other*); education (*≤ 12 years of schooling vs. > 12 years of schooling*) and type of maternity care services (*Public* vs. *Private)* used. Socioeconomic index (SEI) was based on the New Zealand SEI (*<24 vs. ≥24*) with higher values reflecting greater social status (Galbraith, Jenkin, Davis, & Coope, 2003).

Biological measures

Gravidity (*1* vs. *> 1*) was collected at 15±1 weeks' gestation. Pre-pregnancy body mass index (BMI) was calculated from pre-pregnancy weight (kg) divided by measured height squared (m2). BMI was categorised based on WHO guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2)(World Health Organization, 1995).

Psychological and behavioural measures

Based on participant reported consumption, alcohol *(no drinks; 1-2 drinks; 3-7 drinks; 8-14 drinks; >14 drinks)* was categorised as (*drinkers (≥ 1 drink) vs. non-drinkers (no drink)*); and smoking *(no smoking; 1-5 cigarettes; 6-10 cigarettes; >10 cigarettes)* was categorised as (*smokers (≥1 cigarettes) vs. non-smokers (no smoking)*). Women were asked about pre-pregnancy folic-acid supplementation *(no, yes),* and their responses *(dose)* were dichotomized as those meeting the recommended 400 µg vs. those who did not (*Yes* vs. *No*). The questionnaire administered at 15±1 weeks' gestation asked women to report the frequency with which they consumed fruit, vegetables and fish in the first 15 weeks of pregnancy. These responses were used to determine whether they were meeting the recommended five servings of fruit and veg per day (*Yes* vs. *No*), and at least 1 serving of oily fish per week (*Yes* vs. *No*).

Maternal anxiety was assessed using the short form of the State Trait Anxiety Index (STAI)(Marteau & Bekker, 1992), how much stress the woman experienced measured using the Perceived Stress Scale (PSS)(Cohen, Kamarck, & Mermelstein, 1983) and depressive symptoms were assessed using the Edinburgh Postnatal Depression Scale (EPDS)(Peindl, Wisner, & Hanusa, 2004). Pregnancy related behaviour was measured using the behavioural response to pregnancy scale: 'all or nothing' response describes an individual who pushes herself to keep going until they find it physically impossible; 'Limiting' response describes an individual who avoids daily activities (Spence, Moss-Morris, & Chalder, 2005). (See Appendix A, Table 14 for variable codebook and Table 15 for psychological variables and their interpretations (McCarthy et al., 2015)).

Statistical analysis

Secondary analysis was performed using the Irish data from SCOPE in Stata (Version 13). The bio-psychosocial model was used to identify factors that are associated with physical activity in early pregnancy. This model recognises the influences of the biological, psychological, and social dimensions of a person’s life (Figure 6)(Engel, 1981).. Sensitivity analysis was conducted to explore the associations between participant characteristics and the three original physical activity variables (rigorous physical activity, moderate physical activity and recreational walking). An adjusted multinomial logistic regression was conducted for each of the original physical activity measures. Associations between participant characteristics and the physical activity subgroups identified in the latent class analysis were explored using chi-squared test for categorical and ANOVA for continuous variables. Unadjusted multinomial logistic regression was conducted to examine the association between covariates and physical activity level. See Supplementary file 3 for the unadjusted associations. Multivariable, multinomial logistic regression was conducted using a hierarchical approach (Victora et al., 1997) whereby model 1 included the social factors, model 2 added the biological factors, and model 3 was further adjusted for the behavioural and psychological factors. All variables are included in the adjusted model. Estimated coefficients are reported as Relative Risk Ratios (RRR) with 95% confidence intervals (CI) using those who reported low physical activity as the reference category. This is because the exponentiated coefficient in multinomial logistic regression is the ratio of two relative risks (RRR) and is not to be confused or interpreted as an odds ratio (OR). The STROBE checklist was used to inform reporting of the findings.

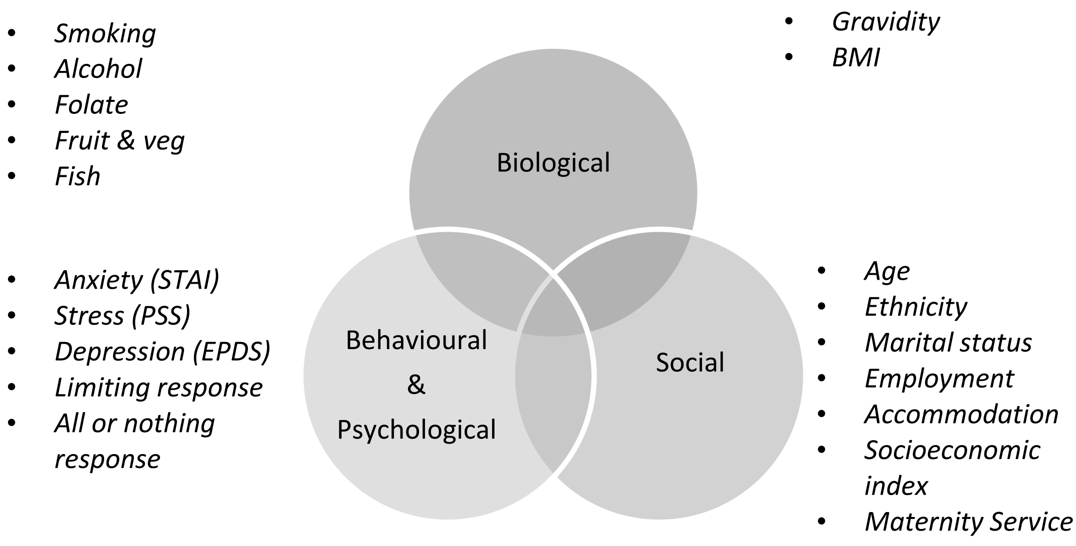

Figure 6: Biopsychosocial model for physical activity

3.4 Results

Sample characteristics

A total of 2579 nulliparous women were invited to participate in the SCOPE Irish study, 1774 (69%) consented to take part. Ages ranged from 17 to 45 (mean age 30, standard deviation 4.5). The SCOPE Ireland women were predominantly Caucasian (n=1733, 98%), married (n=1584, 89%), with > 12 years of schooling (n=1207, 68%), and higher socioeconomic status (n=1469, 83%). The estimated proportions of women in each BMI category were, normal (n=1058, 60%), overweight (n=495, 28%) and obese (n=221, 12%).

Associations between participant characteristics and the three original physical activity variables

A Spearman's correlation was run to assess the relationship between predictors and the three physical activity variables (vigorous physical activity, moderate physical activity and recreational walking). There was a low positive statistically significant correlation between ethnicity, accommodation type, socioeconomic status, alcohol, fruit and veg consumption, oily fish consumption, all or nothing response to pregnancy (women who push themselves during pregnancy) and vigorous physical activity (See Table 16, Appendix A). There was a low positive statistically significant correlation between age, education, ethnicity, marital status, accommodation, socioeconomic status, alcohol consumption, folic acid, fruit and veg consumption and moderate physical activity. There was a low negative statistically significant correlation for maternity service, smoking, anxiety, stress, limiting response to pregnancy (women who avoid activities), and depression and moderate physical activity (See Table 17, Appendix A). There was a low positive statistically significant correlation between age, ethnicity, marital status, accommodation, folic acid, fruit and veg consumption, oily fish consumption and recreational walking. Furthermore, there was a low negative statistically significant correlation for smoking, anxiety, stress, limiting response to pregnancy (women who avoid activities) and depression and recreational walking (See Table 18, Appendix A).

Separate multinomial logistic regressions were conducted for each of the original physical activity measures (vigorous physical activity, moderate physical activity and recreational walking). Results from the fully adjusted model for vigorous physical activity (Table 19, Appendix A) suggest, women who consumed five portions of fruit and veg a day (RRR 1.66 [95% CI: 1.23-2.23]) and oily fish (RRR 1.41 [95% CI: 1.12-1.77]) were more likely to be vigorously activity at least once a week (vs. never). Furthermore, women aged 30-34 (RRR 0.12 [95% CI: 0.16-0.95]) were less likely and those who have been pregnant more than once (RRR 5.81 [95% CI: 1.89-17.91]) were more likely to be vigorously activity at least once a day (vs. never).

Social factors such as age 25-29 (RRR 1.81 [95% CI: 1.16-2.81]) and 30-34 (RRR 1.73 [95% CI: 1.08-2.76]), more than 12 years schooling (RRR 1.49 [95% CI: 1.04-2.13]) and a higher socioeconomic status (RRR 1.61 [95% CI: 1.18-2.20]) were associated with moderate physical activity at least once a week (vs. never) (Table 20, Appendix A).

In the full adjusted model for recreational walking (Table 21, Appendix A), women who were overweight (RRR 1.52 [95% CI: 1.07-2.17), those who were obese (RRR 1.81 [95% CI: 1.07-3.06]) and non-smokers (RRR 1.69 [95% CI: 1.19-2.40]) were more likely recreationally walk at least once a week (vs. never). For the physiological response to pregnancy, women who reported the limiting response to pregnancy (women who avoid activities) was 0.81 time less likely to recreationally walk at least once a day (RRR 0.81 [95% CI: 0.76-0.85]). In addition, those who reported pushing oneself as a response to pregnancy were 1.06 time more likely to recreationally walk at least once a day (RRR 1.06 [95% CI:1.01-1.11]) (vs. never).

Physical activity levels

Physical activity data was available for 1766 women. For the latent class analysis, based on a combination of model fit, parsimony, theoretical interpretability, and classification quality, the authors agreed that a three-class model was the most appropriate one. The three physical activity subgroups thus identified were characterised as follows: *low* levels of physical activity (n = 393); *moderate* levels of physical activity (n = 960); and *high* levels of physical activity (n = 413). Based on chi-squared test and ANOVA, physical activity subgroups were crudely associated with most of the variables considered (Table 3).

Table 3: Social, biological, behavioural and psychological indicators, by physical activity subgroups

Variable		Physical Activity Subgroup (n=1766)		
	n	Low (n =393)	Moderate (n =960)	High (n= 413)
Maternal Age (years)	1774			
Mean (SD)		28.8 (5.0)	30.2 (4.3)	30.4 (4.2)
Ethnicity				
Non- Caucasian	1774	15 (36.6)	23 (56.1)	3 (7.3)
Caucasian		378 (21.9)	937 (54.3)	410 (23.8)
Marital status				
Single	1774	67 (35.6)	83 (44.2)	38 (20.2)
Married/partner		326 (20.7)	877 (55.6)	326 (20.7)
Education				
Schooling ≤12 years	1774	79 (34.5)	103 (45.0)	47 (20.5)
Schooling >12 years		314 (20.4)	857 (55.8)	366 (23.8)
Employment status				
Not working	1774	60 (31.9)	77 (41.0)	51 (27.1)
Working		333 (21.1)	883 (56.0)	362 (22.9)
Accommodation				
Other	1774	173 (28.8)	301 (50.1)	127 (21.1)
Own house		220 (18.9)	659 (56.6)	286 (24.6)
Socioeconomic index				
<24	1774	92 (30.3)	150 (49.3)	62 (20.4)
≥24		301 (20.6)	810 (55.4)	351 (24.0)
Maternity service[a]				
Private	1754	72 (16.5)	258 (59.2)	106 (24.3)
Public		317 (24.1)	696 (52.8)	305 (23.1)
BMI category[c]				
Normal	1774	241 (22.8)	556 (52.7)	258 (24.5)
Overweight		108 (21.9)	270 (54.8)	115 (23.3)
Obese		44 (20.2)	134 (61.5)	40 (23.4)
Gravidity[a]				
1 pregnancy	1754	322 (21.7)	815 (55.0)	346 (23.3)
>1 Pregnancy		67 (24.7)	139 (51.3)	65 (24.0)
Mode of delivery[b]				
C-section	1773	105 (22.3)	265 (56.1)	102 (21.6)
Vaginal birth		288 (22.3)	694 (53.7)	311 (24.1)
Smoking				
Smokers	1774	137 (28.4)	245 (50.7)	101 (20.9)
Non-smokers		256 (20.0)	715 (55.7)	312 (24.3)
Alcohol				
Drinkers	1774	292 (20.6)	778 (55.7)	335 (23.7)
Non-drinkers		101 (28.8)	172 (49.0)	78 (22.2)
Folic-acid supplement[a]				
No	1754	157 (28.0)	285 (50.9)	118 (21.1)
Yes		232 (19.4)	669 (56.0)	293 (24.5)
Five a day[a]				
No	1754	353 (23.4)	822 (54.5)	333 (22.1)
Yes		36 (14.6)	132 (53.7)	78 (31.7)

Table 3: Social, biological, behavioural and psychological indicators, by physical activity subgroups (continued)

Fish[a]				
No	1754	291 (24.2)	647 (53.7)	267 (22.2)
Yes		98 (17.9)	307 (55.9)	144 (26.2)
Anxiety Index	1774	33 (27-43)	33 (27-40)	30 (23-40)
Perceived Stress Scale	1774	14 (9-19)	13 (9-18)	13 (8-17)
Depression Scale	1774	6 (3-10)	6 (3-19)	5 (2-9)
Limiting response	1774	9 (5-12)	8 (6-10)	6 (3-9)
All or nothing response	1774	7 (4-11)	8 (5-11)	8 (5-11)

Data are means (SD) number (%) and median (interquartile range). P-values are for comparisons between the three physical activity levels using analysis of variance (ANOVA), Kruskal-Wallis H or the Chi-square test.

[a]Missing values; [b]Recoded at birth; [c]BMI category defined as World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2)

Multivariable logistic regression findings

In the unadjusted multinomial logistic regression, the majority of social and behavioural factors where linked to either the moderate or high physical activity subgroups or both (See Appendix A, Table 22). Therefore, all variables were included in the final model. Table 4 presents the findings of the multivariable logistic regression analyses with low physical activity as the reference category.

Social, biological, behavioural and psychological

Results from the fully adjusted model (Table 4) suggest, social factors such as women aged 30-34 (RRR 2.27 [95% CI: 1.23-4.22]) and Caucasian (RRR 4.31 [95% CI: 1.14-16.26]) were associated with high physical activity (vs. low). Similarly, having > 12 years of schooling (RRR 1.55 [95% CI: 1.06-2.26]) and a higher socioeconomic status (≥24) (RRR 1.46 [95% CI: 1.05-2.05]) remained associated with moderate physical activity (vs. low).

Accounting for social and biological factors, women who consumed five portions of fruit and veg a day (RRR 1.90 [95% CI: 1.22-2.96]) and oily fish (RRR 1.47 [95% CI: 1.07-2.03]) where more likely to be in the high physical activity subgroup (vs. low), relative to those who did not consume fruit and veg or oily fish. Non-smokers were 1.45 times more likely to be in the high physical activity subgroup (vs. the low) relative to those who reported smoking (RRR 1.45 [95% CI: 1.02-2.07]). For women who did not consume alcohol relative to those who drank, the relative risk for moderate physical activity group (vs. the low) would be expected to decrease by a factor of 0.62 (RRR 0.62 [95% CI: 0.45-0.84]).

For psychological factors, the relative risk for moderate physical activity group (vs. the low), for those who reported avoiding exercise as a response to pregnancy would be expected to increase by a factor of 1.03 (RRR 1.03 [95% CI: 1.00-1.01]) and the relative risk for high physical activity group (vs. the low) would be expected to decrease by a factor of 0.85 (RRR 0.85 [95% CI: 0.81-0.88]) (vs. the low). In addition, those who reported pushing oneself as a response to pregnancy were 1.04 times more likely to be in the high physical activity subgroup (RRR 1.04 [95% CI: 1.01-1.08]) (vs. the low). Of the biological factors, the relative risk for obese women (BMI >30kg/m^2) would be expected to increase (RRR 1.49 [95% CI: 1.00-2.22]) relative to normal (BMI <24 kg/m2) (vs. the low).

Table 4: Hierarchical multinomial logistic regression

Variable	Model 1*		Model 2*		Model 3*	
	Moderate[a] (n =960)	High[a] (n= 413)	Moderate[a] (n =960)	High[a] (n= 413)	Moderate[a] (n =960)	High[a] (n= 413)
Age category						
<25 years	1[c]	1	1	1	1	1
25-29 years	1.56 (1.00-2.45)	1.69 (0.96-2.98)	1.55 (0.98-2.44)	1.71 (0.97-3.01)	1.53 (0.96-2.44)	1.69 (0.94-3.06)
30-34 years	1.55 (0.96-2.50)	2.31 (1.28-4.16)	1.55 (0.96-2.51)	2.33 (1.30-4.19)	1.49 (0.91-2.45)	2.27 (1.23-4.22)
≥ 35 years	1.48 (0.85-2.56)	1.96 (1.01-3.81)	1.48 (0.85-2.57)	2.00 (1.02-3.91)	1.42 (0.80-2.51)	1.98 (0.97-4.01)
Ethnicity						
Non- Caucasian	1	1	1	1	1	1
Caucasian	1.12 (0.54-2.32)	4.23 (1.16-15.44)	1.12 (0.54-2.32)	4.29 (1.18-15.68)	1.01 (0.47-2.16)	4.31 (1.14-16.26)
Marital status						
Single	1	1	1	1	1	1
Married/partner	1.35 (0.87-2.11)	1.31 (0.76-2.25)	1.37 (0.88-2.14)	1.32 (0.76-2.27)	1.25 (0.79-1.98)	1.06 (0.59-1.88)
Education						
Schooling ≤12 years	1	1	1	1	1	1
Schooling >12 years	1.73 (1.20-2.50)	1.49 (0.96-2.30)	1.65 (1.14-2.39)	1.48 (0.95-2.30)	1.55 (1.06-2.26)	1.35 (0.85-2.14)
Employment status						
Not working	1	1	1	1	1	1
Working	1.44 (0.95-2.18)	0.78 (0.49-1.26)	1.48 (0.98-2.26)	0.78 (0.48-1.25)	1.40 (0.92-2.14)	0.66 (0.40-1.08)
Accommodation						
Other	1	1	1	1	1	1
Own house	1.02 (0.75-1.40)	1.06 (0.73-1.53)	1.02 (0.75-1.40)	1.05 (0.73-1.53)	0.99 (0.71-1.37)	1.01 (0.68-1.48)
Socioeconomic						
<24	1	1	1	1	1	1
≥24	1.40 (1.01-1.93)	1.38 (0.93-2.03)	1.44 (1.04-2.01)	1.36 (0.92-2.01)	1.46 (1.05-2.05)	1.47 (0.98-2.21)
Maternity service[b]						
Private	1	1	1	1	1	1
Public	0.82 (0.60-1.12)	0.90 (0.63-1.30)	0.80 (0.58-1.10)	0.91 (0.63-1.30)	0.80 (0.58-1.10)	0.93 (0.64-1.36)

Table 4: Hierarchical multinomial logistic regression (continued)

BMI category[d]						
Normal	-	-	1	1	1	1
Overweight			1.09 (0.83-1.44)	0.97 (0.71-1.35)	1.23 (0.85-1.50)	1.04 (0.74-1.45)
Obese			1.45 (0.98-2.15)	0.91 (0.56-1.46)	1.49 (1.00-2.22)	0.96 (0.59-1.57)
Gravidity[b]						
1 pregnancy	-	-	1	1	1	1
>1 Pregnancy			0.79 (0.57-1.10)	0.88 (0.56-1.46)	0.87 (0.62-1.22)	1.06 (0.71-1.58)
Smoking						
Smokers	-	-	-	-	1	1
Non-smokers					1.34 (1.00-1.80)	1.45 (1.02-2.07)
Alcohol						
Drinkers	-	-	-	-	1	1
Non-drinkers					0.62 (0.45-0.84)	0.75 (0.52-1.08)
Folic-acid[b]						
No	-	-	-	-	1	1
Yes					1.06 (0.78-1.46)	1.17 (0.80-1.70)
Five a day[b]						
No	-	-	-	-	1	1
Yes					1.41 (0.94-2.11)	1.90 (1.22-2.96)
Fish[b]						
No	-	-	-	-	1	1
Yes					1.35 (1.03-1.79)	1.47 (1.07-2.03)
Anxiety Index	-	-	-	-	1.01 (1.00-1.01)	1.00 (1.01-1.01)
Stress	-	-	-	-	1.02 (1.01-1.05)	1.01 (0.96-1.04)
Depression Scale	-	-	-	-	1.01 (1.00-1.04)	1.00 (1.01-1.06)
Limiting	-	-	-	-	1.03 (1.00-1.01)	0.85 (0.81-0.88)
All or nothing	-	-	-	-	1.02 (1.01-1.05)	1.04 (1.01-1.08)

*RRR (95%, CI) *P*

Includes only variables collected at 15±1 weeks' gestation (mode of delivery excluded)

[a]Reference category: low physical activity level; [b]Missing values; [c]1 denotes reference category; [d]BMI category defined as World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2)

3.5 Discussion

Women aged 30-34 years had increased probability of being in the high physical activity subgroup (vs. the low) relative to women <25 years of age. Women with a higher educational level, in a higher socioeconomic status and in the obese BMI category (>30kg/m^2) had increased probability of being in the moderate physical activity subgroup (vs. the low). Non-smokers were more likely to be in the high physical activity relative to smokers. Women who consumed the recommended five servings of fruit and veg per day and at least 1 serving of oily fish per week were more likely to be in the high physical activity subgroup.

Women aged 30-34 years had increased probability of being in the high physical activity subgroup (vs. the low). This is noteworthy given that other studies have reported higher levels of physical activity among younger age groups (Ning et al., 2003). Consistent with previous studies on physical activity, pregnant women with a higher educational level and in a higher socioeconomic status were more likely to engage in moderate levels of physical activity (Chasan-Taber et al., 2007; Foxcroft, Rowlands, Byrne, McIntyre, & Callaway, 2011; Ning et al., 2003). Similar to other studies, factors associated with exercise during pregnancy include income level, the absence of children at home, white ethnicity and activity prior to pregnancy (Gaston & Cramp, 2011). Women with a high education may have access to more information, may be aware of the recommended guidelines and have more time for physical activity during pregnancy (Foxcroft et al., 2011; Schmidt, Pekow, Freedson, Markenson, & Chasan-Taber, 2006). From a public health perspective, a key concern is social inequalities in physical activity, as physical activity participation varies by socioeconomic status, thus favouring those in a higher socioeconomic status (Giles-Corti & Donovan, 2002). Women that don't achieve a high level of education and are of a lower socioeconomic status are less active and should be the focus of intervention efforts. A previous study showed that women with high pre-pregnancy BMI were less active than women with a low pregnancy BMI (Foxcroft et al., 2011). By contrast, the present study showed that pregnant women in the obese BMI category (BMI >30kg/m^2) had increased probability of being in the moderate physical activity subgroup (vs. the low). The relationship between BMI and physical activity observed in this and in other studies is complex. Obese women may be more likely to engage in less strenuous activity or these women may have over-reported their moderate physical activity levels due to the unclear descriptions of physical activity in the survey questions. Moreover, it could reflect perceived exertion where heavier women find themselves performing activity for which they feel like they are exerting themselves, relative to lighter women. Previous interventions for improving physical activity for pregnant women have focused on high risk groups such as obese women(Pearce, Evenson, Downs, & Steckler, 2013). Non-smokers were more likely to be in the high physical activity subgroup relative to smokers, which is consistent with other studies (Chasan-Taber et al., 2007; Petersen, Leet, & Brownson, 2005). Furthermore, women who consumed the recommended five servings of fruit and veg per day and at least 1 serving of oily fish per week were more likely to be in the high physical activity subgroup which indicates some awareness around healthy lifestyle behaviours during pregnancy. Dolan and Galizzi 2015, state that no behaviour sits in a vacuum, and one healthy behaviour can greatly affect another (Dolan & Galizzi, 2015). Furthermore, exercise and fruit and veg consumption have been identified as being in the same behavioural cluster (Nudelman & Shiloh, 2015) and perhaps explains a potential spill over effect to physical activity as women are already engaging in a number of healthy behaviours. Women who drank alcohol during pregnancy were more likely to be in the moderate physical activity subgroup. This coexistence of healthy and unhealthy behaviours was also identified in other studies (Poortinga, 2007). Similar results were found in an Irish sample of adults aged 18 years and over, where the majority of moderate drinkers reported high levels of physical activity (Conry et al., 2011).

This analysis uses data from one of the largest studies of pregnant women (SCOPE). Furthermore, the population-based nature of the study allowed the estimation of the associations of a variety of social, biological, behavioural and psychological factors in a more representative sample than is often possible. Future research should find and use a better measure of physical activity to accurately assess physical activity levels and investigate the frequency, duration and intensity. While demographic correlates of physical activity are informative, they are largely un-modifiable. However, increased understanding of these correlates can be used to guide the development of interventions and to identify those who need the intervention, in this case, women of different cultural backgrounds, low educational attainment and lower socioeconomic backgrounds.

Limitations of this study

This work is secondary analysis of data collected with an observational study design. Inherent to the nature of the secondary analysis, the available data was not collected to address this particular research question. Furthermore, most of the data on maternal lifestyle factors were based on self-report and is susceptible to biased reporting of the lifestyle behaviours and physical activity. Lifestyle factors in the SCOPE study were based on a range of questions from a non-validated questionnaire which should be acknowledged in order to interpret our results. Original survey questions on physical activity including vigorous exercise, moderate exercise and recreational walking used descriptions such as breathing and panting. Social desirability bias may have thus led to women over-reporting their physical activity levels. Although self-report has capacity to over or underestimate true physical activity level, the use of daily exercise leading to heavy breathing or being out of breath has been used in other studies (Bell, Palma, & Lumley, 1995). In order to create a more robust indicator for this study, latent class analysis was conducted to classify pregnant women's physical activity subgroup based on multiple survey questions. The resulting classification should then be less prone to error than classifying participants based on any single question, but given that there is no gold-standard to compare to, we must still rely on our subjective interpretation of the classification. Furthermore, the data from this cross-sectional study does not illustrate exercise conditions throughout pregnancy or the variation in exercise that may occur from trimester to trimester. Previous research advocates for the continuation of pre-pregnancy and early pregnancy physical activity levels into later pregnancy (Norris et al., 2017). Therefore, longitudinal follow up is warranted in future studies.

3.6 Conclusion

This study identifies the links between social, biological, behavioural and psychological factors and physical activity level during pregnancy in a healthy pregnant population. The findings highlight some key potential links including those of a young maternal age, those with a low education level and those from a low socioeconomic background and physical activity. It also highlights potential behavioural clusters and spill over effects to physical activity. These factors should be considered for future interventions to improve physical activity levels during pregnancy.

4 STUDY 2: ENABLERS AND BARRIERS TO PHYSICAL ACTIVITY

Enablers and barriers to physical activity in overweight and obese pregnant women: an analysis informed by the Theoretical Domains Framework and COM-B model

C Flannery, S McHugh, AE Anaba, E Clifford, M O'Riordan, LC Kenny, FM McAuliffe, PM Kearney, M Byrne

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4.1 Abstract

Background: Obesity during pregnancy is associated with increased risk of gestational diabetes mellitus and other complications. Physical activity is a modifiable lifestyle factor that may help to prevent these complications but many women reduce their physical activity levels during pregnancy. Interventions targeting physical activity in pregnancy are on-going but few identify the underlying behaviour change mechanisms by which the intervention is expected to work. To enhance intervention effectiveness, recent tools in behavioural science such as the Theoretical Domains Framework and COM-B model (capability, opportunity, motivation and behaviour) have been employed to understand behaviours for intervention development. Using these behaviour change methods, this study aimed to identify the enablers and barriers to physical activity in pregnant women with overweight and obesity.

Methods: Semi-structured interviews were conducted with a convenience sample of women with overweight and obesity at different stages of pregnancy, attending a public antenatal clinic in a large academic maternity hospital in Cork, Ireland. Interviews were recorded and transcribed into NVivo V.10 software. Data analysis followed the framework approach, drawing on Theoretical Domains Framework and the COM-B model.

Results: Twenty one themes were identified and these were mapped directly on to the COM-B model of behaviour change and ten of the Theoretical Domains Framework domains. Having the social opportunity to engage in physical activity was identified as an enabler; pregnant women suggested being active was easier when supported by their partners. Knowledge was a commonly reported barrier with women lacking information on safe activities during pregnancy and describing the information received from their midwife as 'limited'. Having the physical capability and physical opportunity to carry out physical activity were also identified as barriers; experiencing pain, a lack of time, having other children, and working, prevented women from being active.

Conclusion: A wide range of barriers and enablers were identified which influenced women's capability, motivation and opportunity to engage in physical activity, with "knowledge" as the most commonly reported barrier. This study is a theoretical starting

point in making a ‘behavioural diagnoses’ and the results will be used to inform the development of an intervention to increase physical activity levels among pregnant women with overweight and obesity.

4.2 Introduction

Recent studies identify increasing trends in maternal obesity worldwide and associated complications such as gestational diabetes (Guelinckx et al., 2008; McDonald, Han, Mulla, & Beyene, 2010; Ramachenderan, Bradford, & Mclean, 2008). Maternal obesity also has adverse neonatal outcomes, such as macrosomia (Catalano & Ehrenberg, 2006) and offspring born to obese women are more likely to develop obesity, type 2 diabetes, cardiovascular disease and cancer in later life (Galliano & Bellver, 2013). A recent systematic review identified maternal pre-pregnancy overweight as a significant risk factor for childhood overweight (Weng, Redsell, Swift, Yang, & Glazebrook, 2012). Children of mothers who were overweight before pregnancy were 1.37 times more likely to be overweight at 3 years of age than children of normal weight parents (Hawkins, Cole, & Law, 2008). These trends and risks have increased interest in antenatal interventions which focus on women’s eating, physical activity, their impact on gestational weight gain and gestational diabetes (Hill, Skouteris, & Fuller-Tyszkiewicz, 2013; Luoto et al., 2010; Morisset et al., 2010). Strong evidence exists on the benefits associated with physical activity during pregnancy including an increase in functional mobility and a reduction in nausea and vomiting (Morris & Johnson, 2005; Warburton, Nicol, & Bredin, 2006). Higher levels of physical activity before pregnancy or in early pregnancy also significantly lowers the risk of developing gestational diabetes (Tobias, Zhang, van Dam, Bowers, & Hu, 2011). A recent meta-analysis reported that antenatal physical activity in women of any body mass index led to a small reduction in offspring birth weight (Thangaratinam et al., 2012b). It is possible that this modest reduction in birth weight in offspring of women with overweight and obesity may be beneficial in reducing the long-term obesity risk (Pivarnik et al., 2006; Thangaratinam et al., 2012b). Furthermore, behavioural changes made during pregnancy may continue after childbirth, possibly throughout the woman’s life (Clark & Ogden, 1999) and in turn may have positive effects on child physical activity levels (Hesketh et al., 2017).

Despite these benefits, women’s physical activity levels often reduce or cease during pregnancy (Borodulin et al., 2009). Similar to HSE recommendations in Ireland, American

Congress of Obstetricians and Gynaecologists (ACOG) and the Royal College of Obstetricians and Gynaecologists (RCOG), UK, recommend 30 minutes of daily moderate intensity physical activity for pregnant women (Health Service Executive, 2013; HSE/ICGP, 2013; RCOG, 2006a; Society of Obstetricians and Gynaecologists of Canada, 2003). Previous studies, carried out in different countries, reported low rates of physical activity during pregnancy. In the United States, only 15.8% of pregnant women vs. 26.1% of non-pregnant women reported engaging in the recommended physical activity guidelines [7]. This figure was even lower in a study from Brazil, where only 4.7% of pregnant women were physically active [8]. Only one-fifth of pregnant women in Ireland met the recommended guidelines and over 10% reported no physical activity (Walsh et al., 2011). Furthermore, a study examining lifestyle changes using the Pregnancy Risk Assessment Monitoring system (PRAMS), Ireland found that adherence to physical activity guidelines of moderate intensity activity was low (12.3%) but was particularly low for pregnant women with a body mass index >25kg/m² (6.4%) (O'Keeffe et al., 2016). A cross-sectional study carried out in Danish women who wore a pedometer for at least 5 days, found that mean footsteps were higher among normal-weight women compared to obese women (Renault, Nørgaard, Andreasen, Secher, & Nilas, 2010). Moreover, a decline in physical activity in pregnancy was found in a study carried out in 305 overweight or obese women (Sui, Moran, & Dodd, 2013). These low rates of physical activity during pregnancy, particularly for women with overweight and obesity, are concerning given the significant health benefits for both mother and baby (Morris & Johnson, 2005).

Previous research on clinical effects of lifestyle interventions in pregnant women with overweight and obesity has shown conflicting results (Bogaerts et al., 2013; Guelinckx et al., 2010; Harrison, Lombard, Strauss, & Teede, 2013; Ong et al., 2009; Vinter, Jensen, Ovesen, Beck-Nielsen, & Jorgensen, 2011). These results have been attributed to poor study design, lack of power, lack of consistency in terms of the target behaviour, and failing to identify the psychological determinants and behavioural mechanisms by which the intervention is expected to have an effect (Oteng-Ntim et al., 2012; Rowlands, Graves, de Jersey, McIntyre, & Callaway, 2010). These complex lifestyle interventions have consisted of interacting components including dietary and physical activity counselling, monitoring of weight and group exercise sessions, or have been designed to prevent excessive gestational weight gain and reduce the risk of gestational diabetes

(Campbell, Johnson, Messina, Guillaume, & Goyder, 2011). Other interventions include individual counselling sessions on weight control and motivational interviewing (Claesson et al., 2008; Shirazian et al., 2010). Most of these studies have examined the combined effect of physical activity and dietary advice and guidance. Three randomized controlled trials (RCTs) (Choi, Fukuoka, & Lee, 2013; Ong et al., 2009; Seneviratne et al., 2016) that assessed the isolated effects of exercise in pregnancy on gestational weight gain and clinical outcomes in women with overweight and obesity found no significant difference in gestational weight gain between exercise and control groups. However, a recent meta-analysis (Sanabria-Martínez et al., 2015), found that structured physical exercise programs during pregnancy do decrease the risk of gestational diabetes. Future research needs to address these conflicting results, hence, there is a need to establish the potential effects of physical activity on clinical indicators, especially in pregnant women with overweight and obesity.

Using theory to identify the determinants of behaviour can increase the likelihood that an intervention will be effective (Craig et al., 2008; Michie, Johnston, Francis, Hardeman, & Eccles, 2008). A systematic review (Gaston & Cramp, 2011) examining the determinants of physical activity during pregnancy found that intention to exercise, self-efficacy and barriers such as lack of time and tiredness were strong predictors of exercise. Moreover, a systematic review that evaluated the content of physical activity interventions in pregnancy found theoretically developed interventions were more likely to help reduce the decline of physical activity throughout pregnancy (Currie et al., 2013). Therefore, more attention should be placed on using theory to identify perceived determinants of behaviour and barriers to physical activity behaviour in pregnancy in order to develop effective interventions.

Health psychology offers theories of behaviour that can be used in maternity care interventions to help women make changes to lifestyle behaviours (Campbell et al., 2011; Currie et al., 2013; French et al., 2012). Michie and colleagues developed a framework derived from 33 commonly used behavioural theories and 128 psychological constructs called The Theoretical Domains Framework (TDF). The TDF has been identified as a useful tool for identifying determinants of behaviour and barriers to behaviour change (Table 2). The TDF is an elaboration of the COM-B model which stands for “capability”, “opportunity”, “motivation” and “behaviour” (Michie et al., 2014a;

Michie et al., 2011c)(Figure 1). The COM-B model proposes that for any behaviour to occur a person must have the psychological and physical capability to perform the behaviour; the physical and social opportunity to engage in it and must be motivated to do so. Furthermore, when little is known about the population, qualitative research is useful to develop a theoretical understanding of the target behaviour (Cadogan, McHugh, Bradley, Browne, & Cahill, 2016; Islam et al., 2012; McSherry et al., 2012; Rubinstein, Marcu, Yardley, & Michie, 2015). To date, a number of empirical studies have used either the TDF or COM-B in order to develop behaviour change interventions in different contexts (Alexander et al., 2014; Handley et al., 2016), however to our knowledge this has not yet been done for physical activity in a pregnant population with overweight and obesity.

Therefore, the aim of this study was to use the TDF and corresponding COM-B model to identify enablers and barriers to physical activity in pregnant women with overweight and obesity, and to use this information to inform the development of an antenatal lifestyle intervention programme to improve physical activity levels during pregnancy.

4.3 Method

Study design

A qualitative approach was used. Semi-structured interviews were conducted with a sample of pregnant women with overweight and obesity at risk of gestational diabetes. Ethical approval was obtained from the University College Cork Clinical Research Ethics Committee of the Cork Teaching Hospitals (ref: ECM 4 (y) 06/01/15) (Appendix B).

Sampling and recruitment

Medical chart review identified a convenience sample of pregnant women with a body mass index (≥25kg/m^2) recruited during pregnancy from a public antenatal clinic at Cork University Maternity Hospital, Ireland. Cork University Maternity Hospital is a large academic maternity hospital in the South of Ireland where approximately 6,657 new obstetrics patients entered in 2015 (Cork University Maternity Hospital, 2015). Eligible participants were approached individually and informed about the study by the attending midwife and researcher on site at their antenatal appointment. They were also provided with an information leaflet explaining the purpose of the study, how to participate, and offered a small monetary compensation for participation. A €20 'One for All' voucher for a local shopping centre was posted to each woman who participated once the interview had been completed. Simultaneously, a sub-study examining diet and physical activity behaviours in pregnant African women led by researcher (AEA) was on-going. These women were recruited from the same antenatal clinic during the same period while using the same sampling criteria and interview guide. Therefore, interview data on physical activity for these women were included in this analysis. Data on age, nationality, BMI and gestational age were recorded from medical charts where possible. Gestational diabetes, employment status and miscarriages were recorded only for those women who reported them spontaneously during the interview.

Interview Process

Written informed consent was obtained from all participants at the start of the interviews. Face-to-face interviews were carried out in the antenatal clinic in Cork University Maternity Hospital at a time and day suitable for the participant by two researchers (CF) and (AEA) between June and September 2015. A semi-structured interview schedule was developed based on existing literature (Campbell et al., 2011; Currie et al., 2013; Goodrich, Cregger, Wilcox, & Liu, 2013; Lavender & Smith, 2016; Padmanabhan, Summerbell, & Heslehurst, 2015) and was used to facilitate the discussion (see Table 5). It consisted of open-ended questions and prompts about current lifestyle behaviours (physical activity and diet), challenges to engaging in healthy lifestyle and support mechanisms available. The interview schedule and process were piloted by interviewing two pregnant women at University College Cork. Following this pilot, additional probes and prompts were included to further explore women's experiences in terms of weight management and lifestyle changes. Pilot interviews were not included in the final sample as the women were not eligible for inclusion in the study.

Table 5: Interview schedule used to facilitate the interviews

	Questions	Prompts/Probes
Intro	Tell me a little about your home life?	• First pregnancy? • Married, single? • Other Children – how many? • Employed – how many hours you work?
	Tell me a bit about your lifestyle at the moment?	• Diet – cravings, nausea • **PA** – active before pregnancy, frequency, duration • Have diet/**PA** patterns changed since pregnancy?
Health	Has a HCP made you aware of the risks surrounding your pregnancy	• Excessive weight gain • Gestational diabetes • Potential difficulties during delivery • How does that make you feel?
PA and Diet	What **PA** do you/would you like doing?	• Walking, running, exercises tailored for pregnancy, sports, gym?
	How important do you feel exercise and **PA** is during pregnancy?	• Fitness level • Mobility • Give you more energy • Help sleep
	Tell me what you think would be the best way to encourage women to be watchful of diet and **PA** during pregnancy?	• Through friends, other pregnant women, GP, nurses, information sessions, individual or group, exercise and diet programmes
Behaviour Change	Have you been given advice about dietary habits and **PA** since you became pregnant?	• HCP, family, friend, book, internet? • When was this? • How did you feel about the advice?
	What to do think are the main challenges to **PA** and diet changes during pregnancy?	• Lack of information/ support/ time/ resources
	Would you be interested in using technology to help you track and improve you **PA** and diet	• Mobile phone apps, text message/phone, web based information forums, pedometer? • Would these support mechanisms be useful? • If it provided you with information • If it provided you HCP with your information
	How would you feel about participating in a study where technology used to increase **PA**?	• Mobile phone apps, text message/phone, web based information forums, pedometer • Access to internet, mobile phone
	Is there anything I haven't asked you today you would like to mention?	

Data Analysis

Interviews were recorded and transcribed verbatim. NVivo software was used to facilitate data analysis. Data analysis followed a framework approach (Gale et al., 2013). An inductive thematic analysis was conducted to identify new emerging themes and to investigate a priori objectives using the TDF and COM-B model. Each transcript was read and re-read numerous times by the researcher (CF). Transcripts were coded line by line and analysed to identify similarities and differences. Following open-coding, broader categories were mapped onto the domains of the TDF and then directly onto the six components of the COM-B model identifying emerging themes relating to enablers and barriers to physical activity (see coding frame in Appendix B, Table 23). All transcripts were coded by the researcher (CF) and a subset of interviews were independently coded and analysed by a second researcher (SMH). Minor differences arose in relation to the mapping of codes to the TDF domains, particularly when codes mapped to more than one domain. Differences were resolved by consensus involving a third researcher with expertise in using the TDF and COM-B model (MB) on one occasion, as some themes were coded into multiple TDF domains. Specifically, the domain of "behavioural regulation" and "goals" were merged due to the overlapping theme of action planning. Recruitment continued until new issues ceased to emerge and saturation occurred across the theoretical domains. Two further pregnant women were interviewed to check if any new themes emerged.

4.4 Results

Participants' characteristics

In total twenty two pregnant women with overweight and obesity was interviewed. Data saturation occurred at interview twenty, as subsequent interviews did not contribute to the development of new themes. Eight interviews were included from the sub-study giving the overall sample of thirty pregnant women with overweight and obesity. Table 6 provides details of the participants' characteristics including age, nationality, BMI and gestational age. Gestational diabetes, employment status and miscarriages were only recorded if mentioned by the woman during the interview.

Table 6: Profile characteristics of participants

Nationality	**N=30**
Chinese	2
French	1
Hungarian	1
Lithuanian	1
Irish	16
Nigerian	5
Sudanese	2
Congolese (Democratic Republic of Congo)	1
Ghanaian	1
Age	
20-29	6
30-39	14
40+	1
Unknown[1]	9
Gestation	
First Trimester (0 to 13 Weeks)	1
Second Trimester (14 to 26 Weeks)	8
Third Trimester (27 to 40 Weeks)	20
Not stated	1
BMI (kg/m2\)[2]	
Overweight 25- 29	12
Obese ≥30	12
Unknown[3]	6
Pregnancy	
Singleton	29
Twins	1
Employment	
Working full time	10
Working part time	2
Out sick from work	2
Not working	6
Not stated	10
Gestational Diabetes Mellitus[4]	
Gestational diabetes	5
Not stated	25
Miscarriages[5]	
Miscarriages	8
Not stated	22

[1]*Not recorded from medical chart*
[2]*BMI taken from medical chart (calculated at booking visit by midwife)*
[3]*Midwife identified women as overweight and obese from chart but did not record BMI*
[4]*Only 5 women mentioned having gestational diabetes*
[5]*Only 8 women discussed having one or more miscarriages*

Physical activity clusters identified in pregnancy

From the open coding of the interview data, pregnant women identified a number of factors surrounding physical activity in pregnancy. Given the importance of physical activity during pregnancy and in order to highlight pregnant women's perceptions, these different factors were categorised into four clusters that focus around friends and family, pregnancy, antenatal care and the community. These clusters are summarised in Figure 7. Participants discussed different types of physical activity in pregnancy, the resources available and how family and friends could provide an important supportive role in encouraging physical activity participation. Participants also described the context in which these physical activity behaviours occur. Certain factors identified within these clusters are also present in the TDF and COM-B analysis, see results below. The main type of physical activity identified by the pregnant women includes walking, swimming, pilates, yoga and physical activity classes tailored for pregnancy.

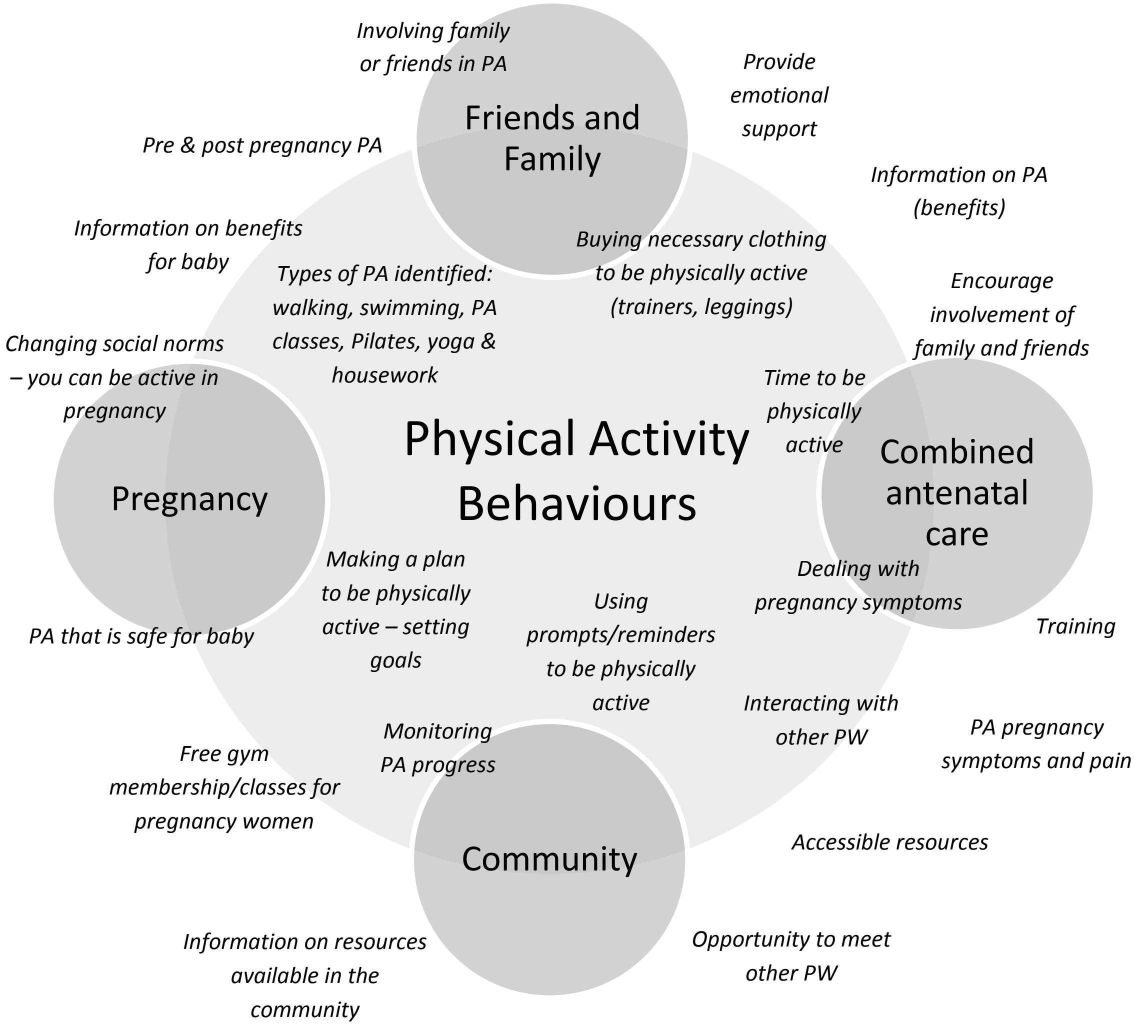

Figure 7: Physical activity clusters identified from the pregnant women interviews

Summary of the TDF and COM-B model

Twenty one themes were identified that mapped directly onto ten of the TDF domains and the six COM-B components. The ten TDF domains included "skills", "knowledge", "behavioural regulation", "goals"; "environmental context and resources", "social influences", "social/professional role and identity", "beliefs about capability", "intentions", and "emotion". The TDF domains not relevant to the context of physical activity in pregnant women with overweight and obesity were "optimism", "reinforcement" "memory" and "belief about consequences". These findings are described in greater detail below using the TDF and corresponding COM-B model (Table 7).

Table 7: Mapping of themes to the theoretical domains framework and COM-B model

Themes	TDF	COM-B
- Fitness level prior to pregnancy - House work as a form of PA - Medical conditions and pregnancy symptoms (pain/energy/tiredness)	**Knowledge** (awareness of the existence of something: knowledge of condition)	**Psychology capability** Knowledge or psychological skills, strength or stamina to engage in the necessary mental process
- Limited knowledge surrounding PA benefits, types of PA in pregnancy and PA resources - Pregnant women discussed concerns around having that 'conversation'	**Knowledge** (awareness of the existence of something: knowledge of condition)	**Psychology capability** Knowledge or psychological skills, strength or stamina to engage in the necessary mental process
- Self- monitoring, use of pedometer/step count/phone apps - Women expressed interest in goal setting	**Behavioural regulation** (managing or changes action – self monitoring) **Goal*** (mental representations of outcome or end states, that an individual wants to achieve)	
- Pregnant woman's situation (family life/children/work/pets) - Financial situation - Weather/ built environment and resources within the community	**Environmental context and resources** (persons situation or environment)	**Physical Opportunity** Opportunity afforded by the environment involving time, resources, location, cues physical affordance
- Acknowledged support from family members, partner and friends - Interaction with other pregnant women [PA classes] was mentioned	**Social influences** (Process that can change thoughts feelings or behaviours – social pressure)	**Social opportunity** Opportunity afforded by interpersonal influences, social cues and cultural norms that influence the way we think
- 'Every pregnant women is different' - Differences in pregnancies	**Social role and identity** (set of behaviours and displayed personal qualities in a social or work setting)	**Reflective Motivation** Reflective process involving plans (self-conscious intentions) and evaluations (beliefs about what is good and bad)

Table 7: Mapping of themes to the theoretical domains framework and COM-B model (continued)

- Using pregnancy as an 'excuse' - Concern for health of the baby - Feeling responsible - Difficulty breaking habits/mind-set	**Beliefs about capability** (acceptance of the truth, reality or validity about an ability, perceived behavioural control, , self-esteem, confidence)	
- Post-partum intentions (planning weight loss/healthy lifestyle)	**Intentions** (A conscious decision to perform a behaviour)	
- Feelings of worry, concern and guilt during pregnancy - Fear based on previous pregnancy outcome/miscarriage	**Emotion** (complex reactions - fear, anxiety, affect, stress, depression, positive and negative effect, burn out)	**Automatic Motivation** Automatic processes involving emotional reactions, desires(wants and needs) impulses inhibitions drive states and reflex responses

** behavioural regulation and goals were merged due to the overlapping construct of 'action planning'*
TDF domain not identified: optimism, reinforcement and belief about consequences.

Capability

Physical Skills

In terms of the domain "physical skills", pregnancy related symptoms were a common reason given by participants for undertaking little or no physical activity. These included muscle pain, pelvic or lower back pain, swelling and other conditions.

> *'The problems I had just stopped me [PA]. Like I got a polyp…which was heavy bleeding and the more I strained the body, even just a swim it was just like there was more pressure on it so I just said it was better to cut everything' (Participant 15; 32 weeks pregnant)*

Furthermore, women who knew their pregnancy was high risk decided themselves that it was best not to engage in physical activity.

> *'I'm a high risk pregnancy so I couldn't do any of the exercise then on this pregnancy. And then I have factor 5 blood so really clotting and all that, I have to take it easy' (Participant 05; 28 weeks pregnant)*

Another barrier was that of feeling too tired to engage in physical activity; finding it hard to move, lack of energy and being physically drained.

> *'It's harder to move faster now that I am pregnant. Like sometimes I have energy and some days I don't… It's difficult, like you feel like you want to do stuff but you can't, your body is just tired and drained physically' (Participant 20; 28 weeks pregnant)*

However, some women felt that physical activity during pregnancy did benefit them (e.g. helped them wake up, gave them energy and made them feel good). Likewise, being physically fit before pregnancy was identified as an enabler; if a woman was active before pregnancy she was more likely to keep it up.

> *'I don't know I think it depends on everyone's circumstances. Like a lot of women would be fit before they got pregnant and they would keep up their walking or running' (Participant 01; gestation unknown)*

House work emerged as an enabler particularly for women who did not like exercise. These women considered household activities as part of their daily activity.

> *'No I wouldn't get out and walk or anything like that…housework would be my activity during the day' (Participant 04; 28 weeks pregnant)*

> *'Not really, there's nothing really, I'm not a big fan of exercise. I will do the house work, the cleaning and the cooking' (Participant 17; 36 weeks pregnant)*

Knowledge

When considering the domain of "knowledge" there was concerns about safety and types of exercise appropriate in pregnancy.

> *'To be honest, I'm not good in what physical activities a pregnant woman should do because nobody really has told me about the kind of exercise you should be doing' (Participant 28; 32 weeks pregnant).*

> *'I mean I don't know can you do certain exercises so I would be worried that I could pull a muscle so I would be extra cautious I suppose at the gym cause I'm afraid and I wouldn't really know' (Participant 13; 32 weeks pregnant)*

These doubts were partly due to the limited information they reported receiving from their midwife or health care professional. This information was described as a *'limited'*, *'quick'*, *'automatic'*, '*like a checklist'* and women felt the benefits of physical activity was rarely discussed.

> *'It's very limited really, very limited. It's a quick one minute conversation really in relation to it [PA/Diet]….I suppose nobody really sits you down to go through the implications of that or the benefits and stuff like that' (Participant 21; 26 weeks pregnant)*

Furthermore when discussing 'the conversation' women felt more emphasis was placed on the clinical aspect of the visit rather than information and advice.

'They don't tend to offer any advice good or bad in terms of weight management and activity and stuff like that. It's more the blood pressure, checking the baby and stuff like that' (Participant 21; 26 weeks pregnant)

Some women felt that midwives assumed, because they had other children, they already had knowledge and information around being physically active in pregnancy.

'…what I found different was when they know that you have children already they kind of thinking that you know everything which is not true…you may forget, years apart, like between now and the last time I had a baby there is a three year gap so I can't remember everything but they seem to assume because you have had other children you know already what to do' (Participant 28; 32 weeks pregnant)

Women actually felt less confident in terms of what they knew about physical activity and would have preferred more advice from their midwife.

'there's no such thing as really showing you or describing it you know, or making sure that you are doing it [PA], I think that could be discussed or checked a little bit more' (Participant 14: 30 weeks pregnant)

Some women were active when they had "knowledge" of the health benefits (e.g. keeping muscles strong for labour). Furthermore, women expressed interest in attending pregnancy exercise classes; if they were provided with information on these classes in their area they would be more likely to attend.

'I think that would be a good idea [PA information & resources], like if you were given like numbers and sort of classes around that area at your clinic appointments for like types of yoga and stuff like that' (Participant 04; 28 weeks pregnant)

Behavioural regulation and goals

In terms of "behavioural regulation" women's comments on technology suggested that action planning and self-monitoring would be an enabler to physical activity. When discussing technology, women explained that a 'pedometer' or 'step count' might help in terms of motivation and to monitor current levels of physical activity.

> *'If there was definitely some sort of measurement like a pedometer or something like that, just something that would flag where you are at and what your targets should be' (Participant 21; 26 weeks pregnant)*

Some women suggested setting "goals" as an enabler to physical activity, providing them with targets to accomplish.

> *'I am very goal driven, I would love that, if someone said ' you need to walk three miles this week and you need to do four laps of the pool and something else, you know you would hit your targets and you know then that even if they say that was helping you, that you are going a good job. You're doing something good anyway' (Participant 18; 14 weeks pregnant)*

Although women felt a pedometer or step count would help with motivation, other forms of technology did not have the same perceived benefit. Women disliked the idea of tracking physical activity (number of days, length of activity time) in a phone app if it was linked with the antenatal clinic. They felt like '*big brother*' would be watching or that it was a chance for their health care professionals to *'check up on me'* calling it an *'invasion of privacy'*. Furthermore some women felt that tracking physical activity would be a *'burden'* or like *'homework'* and that with their busy lifestyles they would just forget.

> *'I'm not actually that good of keeping track of anything really like that [PA] (laughs) I would try to write things down but I would just be so busy or I would forget and I wouldn't do it, so I wouldn't be a good user of those [pregnancy apps]' (Participant 13; 32 weeks pregnant)*

Opportunity

Environmental context and resources

Women's opportunity to engage in physical activity in pregnancy was often hindered by work and family commitments. Even though they were motivated to be physically active, constraints in the way of time and bad weather conditions regularly justified not participating in physical activity.

> *'I suppose prior to the first pregnancy I could go from work to exercise and then come home. Whereas, now if I do that I don't see my son before he goes to bed. So I just can't fit it into my day to be honest, it's more challenging' (Participant 21; 26 weeks pregnant)*

Some women identified a lack of financial means as well as a lack of targeted services specifically tailored for pregnancy as barriers to physical activity. Women suggested subsidised services as a solution to financial difficulties. Making services *'financially viable'* might encourage the use of a gym or exercise class's thus enabling physical activity.

> *'I mean I'm not going just because I have two kids I have a massive big mortgage and I actually can't afford the full membership to go swimming…….Free gym membership for pregnant woman for 9 months (laughs) that would be great, even I would go then (laughs)' (Participant 16; 38 weeks pregnant)*

Social influences

A commonly reported enabler to physical activity was that of "social influences" which included encouragement from family and friends. Partners or husbands were the most influencing factor (e.g. *'always pushing me to go for a walk'*, *'he would drag me out for a walk'*).

The women's husbands were not seen as a barrier to PA while other family members were.

> *'Put your feet up' that's what I get especially over the last four weeks, from my mother in law' (Participant 16; 38 weeks pregnant)*

Women also expressed an interest in pregnancy physical activity classes thus giving mothers a chance to *'talk'* and facilitating a kind of *'support group'*.

'…it would be that extra motivation [PA classes]. Get out and make friends and talk more, and enjoy the activity more' (Participant 04; 28 weeks pregnant)

Motivation

Social role and identity

A clear justification for not engaging in physical activity was the 'individual'. It was commonly reported that *'every woman is different'* and *'every pregnancy is different'* and it was up to that 'individual' whether or not they would make healthy choices or be physically active.

'I think it definitely depends on the individual, I think it depends on the pregnant mother whether they want to be healthy or not…' (Participant 01; gestation unknown)

Belief about capability

When considering "belief about capability" pregnancy was viewed as a time for change particularly for the benefit of the baby '*I just have to… be as healthy as I can be now, I mean it's all for the baby' (Participant 13; 32 weeks pregnant)*. The foremost feelings that prevailed throughout the interviews were the sense of *'responsibility'* in providing the best for the baby in terms of healthy lifestyle behaviours.

'…every woman is different and every woman will take on board information differently [diet & PA]*. I think it is very important when you're pregnant, you need to just take responsibility like, and you do. (Participant 19; 27 weeks pregnant)*

Some women also described how they were changing behaviour to be healthy, not only for the baby, but for themselves.

'..when I came out of my doctor I knew I was going to do something that was going to help me and the baby and that my actions would make us healthier together ya know. (Participant 18; 14 weeks pregnant)

At the same time, pregnancy provided a reason not to make healthy changes (e.g. *'…like sure I'm pregnant. I'm going to be big anyway' (Participant 09; 39 weeks pregnant)).* Woman felt that pregnancy could be used as an *'excuse'* and that *'mind-set'* played a big part in whether or not the individual would make any changes. Some women stated had they been physically active at the start of pregnancy it would have been easier, that breaking bad habits in pregnancy is difficult.

> *'No I would have to have been doing it from the start [PA]. I wouldn't have picked it up half way through. I definitely would have had to have started at the beginning. I mean I told myself at the start, I actually wouldn't mind doing that [PA] and keeping it up but I just didn't and then I just stopped and sat and eat….it's hard to break that habit especially when you are pregnant as you do use it as an excuse' (Participant 02; gestation unknown)*

Intentions

Others reported being motivated when talking about after pregnancy and their implicit intentions to change (e.g *'I have it planned out in my head'*).

> *'I know I am not having any more and I tell myself afterwards I'll get back into it' (Participant 02; gestation unknown)*

> *'So I said right when this baby now is done…after I have recovered I'm going back to my [PA] classes' (Participant 05; 28 weeks pregnant)*

Emotion

In terms of "emotion", enablers to physical activity included feelings of *'guilt'* and *'concern'*.

> *'if I could get away with it [no PA], if I could I would definitely but I know I would feel pure guilty. I know I would have then looking at me and I would feel fierce guilty' (Participant 18; 14 weeks pregnant)*

'…the first time round I could go for walks, I was taking care of my health and ya know, you kind of that bit worried the first time round, you make sure you are doing the best for the baby and yourself' (Participant 01; gestation unknown)

A fear based on previous pregnancy outcomes was highlighted with women afraid to do anything in pregnancy due to previous miscarriage experiences.

'…from the moment I knew I was pregnant it has been terrifying for me. Because like I'm after having 3 miscarriages in 2 years it's not a nice thing to experience, I mean you're constantly waiting to see that heartbeat..' (Participant 05; 28 weeks pregnant)

4.5 Discussion

The aim of this study was to systematically identify the barriers and enablers to physical activity for women with overweight and obesity in pregnancy using the TDF and COM-B model. A wide range of barriers and enablers were identified which influenced women's capability, motivation and opportunity to engage in physical activity with women providing more information about barriers than enablers.

In the current study, the most commonly reported barrier to physical activity during pregnancy was "knowledge". It was clear from the findings that women were unclear on what types of physical activity they could engage in while pregnant and whether physical activity was safe. These findings are similar to that of a qualitative study conducted in the US, in which pregnant women mentioned a lack of advice regarding physical activity (Evenson, Moos, Carrier, & Siega-Riz, 2009); the most information they received from their midwives was to 'carry on as usual' (Weir et al., 2010). Perhaps this lack of information can explain why adherence to physical activity guidelines is so low particularly for pregnant women with a BMI >25 kg/m^2 (6.4%) (O'Keeffe et al., 2016). Health care professionals are key to enhancing pregnant women's knowledge of being physical active and the benefits of being active in pregnancy (van der Pligt, Campbell, Willcox, Opie, & Denney-Wilson, 2011). Furthermore, many women received little or no advice on appropriate weight management in pregnancy. Service providers (Oteng-Ntim et al., 2010), similar to the women here, considered verbal advice offered to women on topics such as lifestyle and weight management to be inconsistent and unsupported by written information (Olander, Atkinson, Edmunds, & French, 2011). This is perhaps not surprising given the lack of Irish guidance regarding weight management in pregnancy (Health Service Executive, 2013). However, despite this the women actually expressed little concern about weight gain.

"Physical skills" such as pregnancy-related symptoms (e.g. morning sickness/nausea/pelvic pain) were common barriers to physical activity. However, research has shown that being physical active in early pregnancy can reduce these symptoms (Morris & Johnson, 2005; Warburton et al., 2006). Thus this information may be a useful motivational strategy to encourage women with overweight and obesity to be active early on. Furthermore, high risk pregnancies were identified as a barrier, yet, research has indicated that in the case of risk factors for preeclampsia, exercise has been seen to promote maternal circulation, improve maternal fetal vascularity and boost the immune system of women (Mparmpakas et al., 2013). For women with high risk pregnancies, physical activity is recommended with some restrictions; but there are currently no clear recommendations available (Kasawara, Surita, & Pinto ESilva, 2016), therefore, evidence based guidelines are required for health care professionals in order for them to guide women about safe activity in pregnancy given their health status. Another barrier reported by the women was tiredness and a lack of energy due to the pregnancy, work, and family commitments. This is consistent with previous literature as feeling tired or having no energy are the most commonly reported reasons for not being active (Downs & Hausenblas, 2004; Duncombe, Wertheim, Skouteris, Paxton, & Kelly, 2009; Evenson et al., 2009; Leiferman, Swibas, Koiness, Marshall, & Dunn, 2011).

These women identified "social influences" indicating the relative importance of advice received from family and friends in initiating physical activity behaviour. Also, the women enjoyed meeting other pregnant women and expressed interest in physical activity classes tailored for pregnancy. Healthcare professionals need to take a holistic approach to care, taking into consideration the women's social support network and influences to include their partners in group pregnancy sessions. Action planning and goal setting were identified by the women as a means of motivation while pedometers and step counts could help with self-monitoring. A review, examining the use of pedometers to increase physical activity and improve health, concluded that pedometers were associated with significant increases in physical activity in an adult population (Bravata et al., 2007). In addition, in a study with pregnant women the pedometer was acceptable form of monitoring (Renault et al., 2010). Thus, future interventions should include some component of self-monitoring in order to improve physical activity levels in pregnant women with overweight and obesity.

Analysis using the TDF provided a detailed understanding of the barriers and enablers to physical activity for pregnant women and the refinement of the findings into the COM-B model has set the stage for developing a theory and evidence based intervention to increase physical activity levels in pregnant women with overweight and obesity. Using these frameworks added substantial strength to this study because it is composed of theoretically derived domains based on a comprehensive list of behavioural theories. This will help to identify potentially relevant domains and to select a set of relevant theories to investigate the target behaviour in depth at a later stage. While the study has some clear strengths, there were some potential limitations. While the TDF provided a comprehensive framework for understanding types of enablers and barriers to physical activity among this population, at times it was difficult to categorise themes due to lack of clarity in the definitions of the theoretical domains. Where this happened, the best solution was determined through discussion with members of the research team (CF) and (SMH). An additional limitation was the sampling frame for the study; all women were recruited through a public clinic in one maternity hospital setting potentially limiting diversity in study findings. Although this ethnically diverse sample of pregnant women shared similar views regarding physical activity, research is warranted to assess racial or cultural differences in pregnant women with overweight and obesity.

4.6 Conclusion

This research provides an important overview of the behavioural factors enabling or inhibiting physical activity and has also identified a system of behaviours that may be relevant in order to increase physical activity levels amongst pregnant women with overweight and obesity. Using the TDF and COM-B model is a theoretical starting point for understanding behaviour within specific contexts and to make a ‘behavioural diagnosis’ of what needs to change to alter behaviour. The COM-B model forms the hub of the Behaviour Change Wheel (BCW) which provides a systematic and transparent way to conduct a behavioural assessment, identify the target behaviour, select intervention functions and to develop theory based intervention strategies (Michie et al., 2011c). The findings suggest a lack of knowledge around safe types of physical activity in pregnancy and awareness of the potential benefits for mother and baby. Interventions which provide continuing support from health care professionals and involve partners and family members are potential approaches to consider for interventions in pregnancy. In future research, we will use the behaviour change wheel to identify intervention functions to systematically develop a lifestyle intervention to increase physical activity levels for pregnant women with overweight and obesity. Developing an antenatal intervention that targets these salient barriers to physical activity will have greater potential to change behaviour.

5 STUDY 3: HEALTH CARE PROFESSIONALS EXPERIENCES

Exploring obstetricians, midwives and general practitioners approach to weight management in pregnant women with a BMI ≥25: a qualitative study

C Flannery, S McHugh, L Kenny, MN O'Riordan, FM McAuliffe, C Bradley, PM Kearney, M Byrne

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5.1 Abstract

Background: The aim of this study was to understand the approach taken by midwives, obstetricians and General Practitioners (GPs) who provide antenatal care to pregnant women with a BMI ≥25 with the view to informing the development of an antenatal lifestyle intervention.

Method: Semi-structured interviews were conducted with a convenience sample of health care professionals from a large academic maternity hospital in Cork, Ireland and with a sample of GPs working in primary care in the region. Interviews were digitally recorded and transcribed into NVivo V.10. Thematic analysis was used to analyse the data.

Results: Seventeen health care professionals were interviewed (Hospital based=10; GPs=7). Four themes identified the complexity of weight management in pregnancy and the challenges HCPs faced when trying to balance the medical and psychosocial needs of the women. Health care professionals acknowledged weight as a sensitive conversation topic, leading to a "*softly-softly approach"* to weigh management. Health care professionals tried to strike a balance between being woman-centred and empathetic and medicalising the conversation. Health care professionals described "*doing what you can with what you have*" and *shifting the focus to managing obstetric complications*. Furthermore, there were *unclear roles and responsibilities* in terms of weight management.

Conclusion: Four themes identified by health care professionals reflect the complexity of weight management and the challenges faced when trying to balance the medical and psychosocial needs of the women. Health care professionals need to have standardised approaches and evidence-based policies that support the consistent monitoring and management of weight during pregnancy.

5.2 Introduction

The prevalence of overweight and obesity during pregnancy is increasing (Dodd et al., 2010). Although some weight gain is to be expected during pregnancy, many women appear at their first antenatal appointment with a Body Mass Index (BMI) ≥25 kg/m^2 representing a significant and increasing problem faced by health care professionals (HCPs) in obstetric practices (Dodd et al., 2010; Health Service Executive, 2013). Recent studies, in Ireland, reported that between 19% and 25% of women were categorised as overweight or obese in the first trimester (Fattah et al., 2010) or at their first antenatal visit (Lynch et al., 2008). Furthermore, obesity in women was most widespread in high income countries with a prevalence of 25% in the UK and 34% in the USA (Ng et al., 2014). In Europe, the prevalence of overweight and obesity among pregnant women ranged between 33% and 50% (World Health Organization, 2008)

Overweight is defined as BMI ≥25 kg/m^2 and obesity is defined as a BMI ≥30 kg/m^2 which is assessed at the first antenatal consultation (National Research Council, 2010). Gestational weight gain (GWG) is the total weight gained during pregnancy, with the largest weight gains generally occurring in the second and third trimester (Centre for Public Health Excellence at Nice National Collaborating Centre for Primary, 2006; National Research Council, 2010). The Institute of Medicine (IOM) recommends different gestational weight gain for each BMI category (Nascimento et al., 2011; National Research Council, 2010). These guidelines are individualised to pre-pregnancy BMI and are based on evidence of weight gain patterns in pregnancy and on health outcomes for mother and baby. A recent review that compared national gestational weight gain guidelines and energy intake recommendations found that 31% of countries were adopting these gestational weight gain guidelines (Alavi et al., 2013). Furthermore, after two different searches of available guidelines, the authors of the review found no gestational weight gain guidelines or recommendations available for Ireland (Alavi et al., 2013).

Problems associated with obesity during pregnancy include an increased risk of hypertensive disorders, higher rates of caesarean section and preterm delivery (Johnson et al., 2013). Moreover, excessive GWG in pregnancy increases the risk of developing gestational diabetes mellitus (GDM) and is a strong risk factor of long term obesity (Hernandez, 2012; Herring, Rose, Skouteris, & Oken, 2012; Rooney & Schauberger, 2002). Obesity also presents a greater risk of perinatal complication such as macrosomia (Heiskanen, Raatikainen, & Heinonen, 2006). Recent literature reviews have identified diet and lifestyle interventions as a means of reducing the risk of GWG, GDM, and postnatal weight retention (Campbell et al., 2009b; Messina et al., 2009; Thangaratinam et al., 2012c). However, due to the poor quality of these studies and heterogeneity in the intervention designs the results should be interpreted with caution and uncertainty persists around their effectiveness (Oteng-Ntim et al., 2012).

While the delivery of antenatal care is different in many countries, a number of HCPs, including hospital-based HCPs (such as midwives and obstetricians) and general practitioners (GPs) provide care throughout pregnancy (Stotland et al., 2010). In Ireland, antenatal care is shared between hospital based HCPs and GPs (Hanafin & Dwan O'Reilly, 2016). Pregnancy has been identified as a "teachable moment" where woman's health motivations could be harnessed for long-term behaviour change and wider public health benefits beyond pregnancy, given women's vital role in supporting healthy lifestyles in the wider family unit (Phelan, 2010). The regular interactions between HCPs and women during pregnancy provide opportunities to support women to achieve positive lifestyle changes, particularly in terms of weight management (van der Pligt et al., 2011; Widen & Siega-Riz, 2010). While these HCPs have been identified as vital contributors to the antenatal services, in Ireland, little is known about the ways in which such professionals engage with pregnant women with overweight and obesity. HCPs have key opportunities to influence lifestyle and weight management in this shared care arena which are not currently fully availed of (Campbell, Engel, Timperio, Cooper, & Crawford, 2000; Heslehurst et al., 2011).

Few studies in Ireland focus on the approach taken by HCPs regarding antenatal lifestyle advice and weight management (Biro et al., 2013; Olander et al., 2011; Stewart, Wallace, & Allan, 2012). Little is known about the use of guidelines in clinical practice and whether HCPs address the needs of pregnant women with overweight and obesity. A survey among obstetrics and trainee doctors in the United States found little knowledge of the revised Institute of Medicine (IOM) guidelines for appropriate GWG (Moore Simas et al., 2013). Over half of those surveyed were not aware of the new guidelines and less than 10% selected the correct BMI ranges or the correct GWG ranges. Previous qualitative studies have highlighted a number of barriers to weight management for

HCPs including communication difficulties between health care professionals and patient (Furness et al., 2015), lack of confidence and training to provide weight advice (Davis et al., 2012) and a lack of resources within antenatal care (Heslehurst, Lang, Rankin, Wilkinson, & Summerbell, 2007b). Understanding the ways in which HCPs currently manage maternal obesity in an Irish context is necessary to inform the development of antenatal lifestyle interventions. Therefore, the aim of this study was to explore HCPs beliefs and attitudes towards weight management and their approach to working with pregnant women with overweight and obesity at a large academic maternity hospital in Cork, Ireland and primary care settings in the same region.

5.3 Methods

Study design

A qualitative study was conducted to understand HCPs experiences of weight management for pregnant women with overweight and obesity. Ethical approval was obtained from the University College Cork (UCC) Clinical Research Ethics Committee of the Cork Teaching Hospitals (ref: ECM 4 (y) 06/01/15) (Appendix B).

Sampling and recruitment

A convenience sample of hospital based HCPs were identified at Grand Rounds from a public antenatal clinic in a large academic maternity hospital, Cork University Maternity Hospital, Ireland. Hospital based HCPs included midwives and consultant obstetricians who provide care for women either during pregnancy, labour and birth, or in the postnatal period. GPs in the Cork-Kerry region were identified using a GP list provided by the Department of General Practice, UCC, which included GP names and contact details. GPs were convenience sample based on gender and location of practice (urban/rural). GPs were recruited from single or group practices serving both public and private patients. HCPs were eligible if they were engaged in clinical practice during the time of the study and regularly consulted with pregnant women with a BMI ≥25kg/m^2. HCPs were provided with an invitation letter and study information sheet and were informed that (CF) was conducting this research as part of her PhD work. Follow up phone calls were made to determine if they were interested in participating.

Interview process

Face-to-face semi-structured interviews were carried out by a single trained qualitative researcher (CF) at the hospital antenatal clinic or in the primary care setting between January and July 2016. Written informed consent was obtained from all HCPs prior to the interview. The topic guide was developed based on previous literature (Campbell et al., 2009a; Chang, Llanes, Gold, & Fetters, 2013; Hill et al., 2013; Johnson et al., 2013). Key areas for discussion included addressing weight, lifestyle advice and resources and supports available (Appendix B, Table 24). The topic guide and interview process were piloted by interviewing two HCPs (a midwife working in Australia and a nurse no longer involved in clinical practice). Following this, refinements were made to the prompts used to ensure the interview was designed to capture HCPs experiences. Pilot interviews were not included in the final sample. Data saturation was defined as being reached when no new themes emerged (Silverman, 2016).

Data Analysis

Interviews were audio recorded and transcribed verbatim. NVivo software was used to facilitate data analysis. Thematic analysis as described by Braun and Clarke, 2006 was used to analyse the data (Braun & Clarke, 2006). An inductive approach was used, where; transcripts were read and open-coded. These codes were grouped according to HCPs beliefs and attitudes, their approach to weight management and the reasons for this approach. Codes, and categories where discussed and sub-themes were synthesised and organised to develop broader themes (CF and SMH). The data were analysed independently by one researcher (CF) with a subset of the transcripts dual coded (CF and SMH). To ensure the consistency of the findings an audit trail was kept for transparency in the analysis. Hospital based HCPs and GPs were reported as HCPs when similar views and attitudes were expressed. Differences between hospital based HCPs and GPs were also recorded. The consolidated criteria for reporting qualitative research (COREQ) statement was used to inform reporting of the findings.

5.4 Results

Thirty-six HCPs were invited; seventeen participated (hospital based n=10) and (GPs n=7). The 17 interviews were analysed chronologically. With no new themes emerging it was agreed that no more interviews were required. Table 8 provides details of the participants' characteristics including gender, occupation and location of practice. The interviews for hospital based HCPs ranged from 23 to 50 minutes in duration and GP interviews ranged from 14 to 35 minutes.

Table 8: Profile characteristics of HCPs (N=17)

	Male	**Female**
Occupation		
Midwife [A]	**-**	**4**
SHO Senior House Officer	**-**	**1**
Consultant Obstetrician [B]	**2**	**3**
General Practitioners	**3**	**4**
Location		
Cork	**4**	**12**
Kerry	**1**	**-**

[A] Midwife working in diabetic clinic (n=1); labour ward (n=1); outpatient department (n=2)

[B] Obstetrician's working in obstetrics with sub-specialist interests such as maternal medicine, high risk pregnancies, fetal medicine and complicated pregnancies (n=4); gynaecology (n=1)

Four major themes were identified that relate to HCPs attitudes and approaches to weight management: the *"softly-softly" approach to weight management*; *"doing what you can with what you have"*, *shifting the focus to* the *management of obstetric complications* and *unclear roles and responsibilities for lifestyle advice.* Together these four themes reflect the complexity of weight management and how hospital based HCPs and GPs discuss and approach weight management. Furthermore, HCPs describe the constraints within the system and highlight their attitudes to weight during pregnancy. Hospital based HCPs and GPs shared similar views in terms of weight management, with differences emerging on issues such as weighing practices and concerns about who is ultimately responsible for the management of pregnant women with overweight and obesity. The themes are presented in Figure 8.

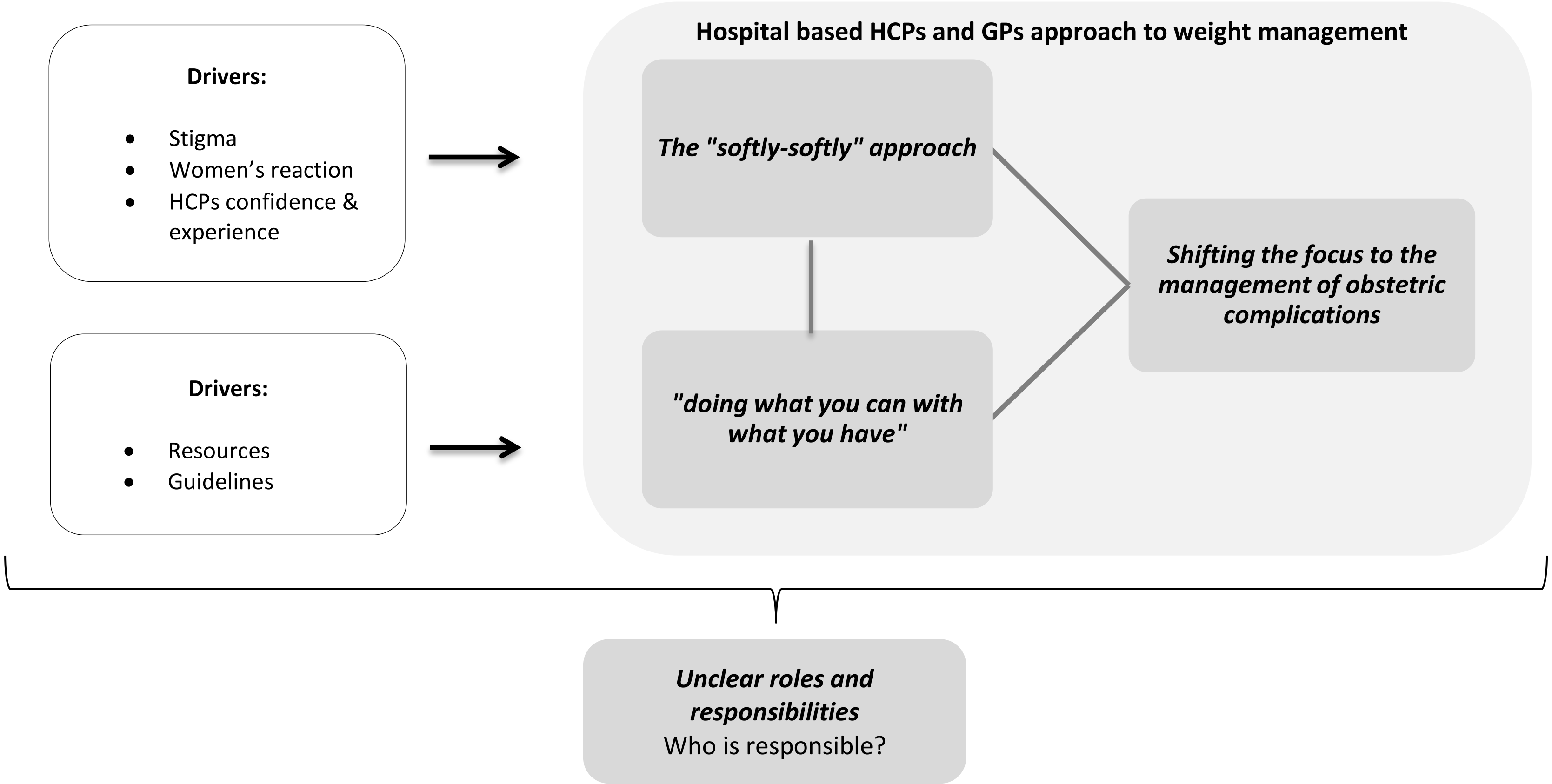

Figure 8: Drivers and approach to weight management for pregnant women with overweight and obesity (additional quotes can be found in Appendix B, Table 25)

The "softly-softly" approach to weight management

Hospital based HCPs and GPs identified the tension between attitudes towards weight at a population and individual level. At the population level, concerns were clear about the dramatic increase in maternal obesity and the attitude that '*being overweight is fine...people look at themselves and say, "Well, I'm just the same size as her." or "I'm thinner than her", therefore, I'm not overweight (Obstetrician 03)*. Furthermore, socialisation and family norms have resulted in unhealthy learned behaviours and an environment in which obesity is now acceptable; "*we're normalising obesity, it's not perceived as a problem"(GP 05)*. Despite this, at an individual level when managing maternal obesity, HCPs recognised the presence of stigma relating to weight and obesity. As a result, a "*softly-softly" approach to weight management* among pregnant women with overweight and obesity was adopted.

> *"…we have a very softly-softly approach to obesity and overeating and over nourishment…" (Obstetrician 07)*

This cautious and diplomatic approach involved trying to strike a balance between being empathetic towards the women, medicalising the issue and acknowledging their duty as HCPs to inform the woman about the risks associated with overweight and obesity. This approach was used to raise and address the topic of weight throughout pregnancy.

The approach depended on how the women reacted to initial attempts to discuss weight and thus varied across women. In participants' experience, most women reacted negatively to the topic of weight and obesity in pregnancy; they disengage, the shutters come down, they can get a bit defensive or dismissive of it and thus it's not a two-way interaction.

Hospital based HCPs and GPs were conscious of the patient experience and that their professional role required them to be sensitive, non-judging, encouraging, motivating and to act as a counsellor for each of their overweight patients. They were concerned about using the right language so as not to cause offence, anger or upset and they acknowledged that you cannot use the word *"fat"*. However, in some cases HCPs highlighted the need to be upfront and blunt to get the message across. Hospital based

HCPs also recognised the need to be clear, to state the facts and to be honest with the woman as it is their responsibility to help the woman manage her weight.

> *"No, I think we need to find a way of getting that message across and I think part of that is just normalising it…we've got to normalise chatting about weight….I've tried a whole range of different ways and sometimes it's regarded as confrontational and I can feel that they're looking at me thinking, "Well, I don't like that doctor." It's not that I'm trying to make her feel bad, I want to point this out and I try and medicalise it and say, "Well, you know your body mass index is over 30, that means you're obese, that puts you at risk of high blood pressure, diabetes" (Obstetrician 03)*

Broaching the subject of weight

Hospital HCPs and GPs felt the need to adopt a *"softly-softly"* approach in relation to the topic of weight compared to a more direct approach they might take with issues such as blood pressure. Raising the subject of weight was influenced by confidence and experience. Some HCPs considered themselves experienced enough to discuss *"uncomfortable truths"* about obesity such as potential complications. Others found it difficult to broach the subject; in particular hospital based HCPs such as junior midwives found raising the topic awkward. To facilitate the conversation, more experienced hospital based HCPs drew on their personal weight issues to relate to the women.

> *'...I'm not the skinniest person in the world. I think it's easier when you can say, "Look, we all have our challenges and you've got to work hard at it"' (Obstetrician 06)*

More detached approaches were also described; with hospital based HCPs using tools such as a BMI categorisation tool to frame the conversation because using BMI "*isn't as upsetting to somebody as if you said, You're fat." (Midwife 01).* Furthermore, because of women's weight, difficulties were often experienced when palpating a woman's abdomen and conducting fetal scans, offering an opportune situation to raise the issue and to discuss the potential complications.

"I actually say it straight out to them when I am scanning, look unfortunately you carry the extra adipose tissue I am finding it difficult , there is too much fat around you abdomen which you need to watch. I would say that straight-out…" (Midwife 01)

All HCPs acknowledged that conversations about weight occur frequently throughout pregnancy as they have continuous contact with pregnant women. However, these discussions were quick conversations due to large caseloads, time and due to the number of topics that needed to be addressed within the consultations. "*it would be a couple of minutes given to a discussion about their weight and the problems with it…" (Obstetrician 09)*

"Doing what you can with what you have" to support the management of overweight and obesity

In the current *"obesogenic environment"* HCPs faced numerous challenges when supporting women to manage their weight. It was identified that the woman's health, their level of risk in pregnancy and scarce resources dictated what HCPs could do to support women's weight management efforts.

Hospital based HCPs were adapting the evidence to deal with large caseloads of women with high BMIs *"...so we don't talk about weight to the women who are overweight, we save that for the women who are obese..."(Obstetrician 03).* Due to scarce resources, priority was given to the obese women rather than overweight women: *"we have far too many women with BMIs in the 40s or even in the 50s in whom we focus our limited resources" (Obstetrician 03)* therefore, women with a BMI ≥25 "*doesn't raise as much of a red flag"*. Limited dietetic services within the hospital were discussed as an example of the inadequate resources, with this service only offered to those with a diagnosis of GDM. This reflected the *"doing what you can with what you have"* approach as hospital based HCPs could do more for these pregnant women. Hospital based HCPs emphasised that this service needed to reach all women, particularly women with overweight and obesity (without GDM) who could benefit from that type of intervention. Also, access to dietetics influenced GPs' management of weight; long waiting times for referrals meant that they lost that window to intervene with the woman.

Most hospital based HCPs did not have any *'specific written guidelines'* to follow while others described using and applying varying ranges of weight gain in pregnancy. A BMI ≥30kg/m^2 was so common, it was considered a low priority for services, management and advice rendering some guidelines *'inadequate'*.

> *'I think the guidelines and the public health policies that are out there are inadequate…..they're certainly not permeating into a lot of healthcare professionals' consciousness and I think many doctors don't regard a BMI of 30 [as priority] because it's becoming more and more common' (Obstetrician 07)*

The '*doing what you can with what you have'* approach to weight management was also reflected in weighing practices and attitudes towards weighing. Weighing practices varied amongst the HCPs and there were divergent attitudes towards its usefulness and appropriateness. GPs highlighted that the evidence and guidelines no longer recommend weight as a *'clinical indicator'*.

> '*...it was stopped being done as routine because it wasn't correlating with health outcomes. That's my understanding of it, but I certainly would be interested to see if there are new guidelines about it. So if it is significant, I think it should be included in the chart…' (GP 03)*

However, hospital based HCPs such as midwives were keeping track of women's weight, particularly at the booking visit and again at 28 weeks. Weight and BMI was used in the hospital to refer women for anaesthetic assessment to determine the woman's *'anaesthetic risk'.*

Shifting the focus to the management of obstetric complications

The risk of obstetric complications at any stage in pregnancy takes precedent over efforts to manage weight with hospital based HCPs acknowledging *"it's too late [to manage weight] at that stage"*. For hospital based HCPs, weight management was superseded when obstetric complications arose. At this point the woman's complications required obstetric care, shifting the focus to the immediate health of the woman and baby.

"If they develop hypertension, I talk about hypertension and the treatment of. It's very difficult at that point, they're now hypertensive, the baby's at risk of growth restriction, they're at risk of early delivery, we need to get their blood pressure under control, take care of the maternal problems and make sure the foetus is okay. It's too late at that stage to start going, "Oh well, you have this now because you're fat." no, it's too late" (Obstetrician 03)

Unclear roles and responsibilities for lifestyle advice

In the context of shared maternity care, HCPs highlighted the challenge of providing continuity of care and questioned who is ultimately responsible for managing weight. It was difficult for hospital based HCPs to provide continuous weight management and advice as they had limited opportunity to follow up with the same women. Therefore, responsibility of continuous care fell to the GPs. Hospital based HCPs suggested the GP would have a better family picture and would have the opportunity to engage with these women on numerous occasions preconception and throughout pregnancy.

"I think there GP should be one that keeps an eye on it [weight], he is the continuous person that's with them" (Midwife 01)

In contrast, GPs tended to put onus on the hospital based HCPs, reporting *"Oh well look, the hospital will take care of that" (GP 05)* or we are very stretched in general practice. Even though both hospital based HCPs and GPs are taking part in shared antenatal care, GPs felt there was little communication between primary and secondary care and more clarity was required around role responsibilities and expectations within the shared care setting. This would ensure that weight related conversations were consistent and reliable.

5.5 Discussion

This qualitative study demonstrates the challenges surrounding weight management during pregnancy for women with overweight and obesity from the perspective of hospital based HCPs and GPs with more concerns for women in the higher BMI categories. Four major themes were identified: the *"softly-softly"* approach, *"doing what you can with what you have", shifting the focus to* the *management of obstetric complications*, and *unclear roles and responsibilities for lifestyle advice.* These themes reflect how HCPs discuss and manage weight, and the challenges they face when trying to balance the medical and psychosocial needs of the women.

The *"softly-softly"* approach is defined as cautious and patient and avoids direct action or force which reflects HCPs accounts of their approach to providing care pregnant women with overweight and obesity. Similar to this study, previous research identified an increased acceptance of obesity within the population (Heslehurst et al., 2011; Johnson, Cooke, Croker, & Wardle, 2008; Kirk, Cockbain, & Beazley, 2008; Schmied, Duff, Dahlen, Mills, & Kolt, 2011) with fewer people now defining themselves as overweight and obese and underestimating their weight status (Howard, Hugo, Taylor, & Wilson, 2008; Johnson et al., 2008; Kirk et al., 2008). Furthermore, stigma in relation to obesity was also present in this study and in previous research with HCPs feeling the discomfort and awkwardness around weight conversations in pregnancy (Schmied et al., 2011). A lack of confidence and experience determined the approach used to broach the subject of weight, with younger midwives in particular finding the topic awkward. This is supported by existing literature, with junior HCPs having negative opinions about their skills for treating obese patients (Biro et al., 2013; Block, DeSalvo, & Fisher, 2003; Brown & Thompson, 2007). Hospital based HCPs and GPs in this study were aware that weight needs to be addressed with care, to avoid upsetting the women. Similarly, in other studies, HCPs were concerned about victimising the women or jeopardising their relationship with the women when raising the subject of weight (Biro et al., 2013; Heslehurst et al., 2007b; Heslehurst et al., 2011). Midwives tried to broach the subject of weight by discussing their own weight loss journeys. In contrast, a study exploring the experiences of HCPs found that HCPs with high BMIs felt they were not in a position to address weight and therefore veered away from the conversation (Brown & Thompson, 2007). Standardised questions could be used with all pregnant women to reduce stigma associated with the conversation of weight and increase HCPs' confidence (Lee, Haynes, & Garrod, 2010). Experienced, well-informed HCPs need to share their training, knowledge and experience with more junior staff, including prompts and communication strategies, in order to improve addressing the subject of weight (Furness et al., 2015). Scarce resources determined HCPs' approach to managing weight, particularly dietetic services which were consequently limited to women with GDM. Similarly, previous research identified limited resources available within maternity units as a barrier to managing weight during pregnancy (Heslehurst et al., 2011; Schmied et al., 2011). With a number of diet and physical activity interventions reducing GWG and GDM (Koivusalo et al., 2016; Oteng-Ntim et al., 2012; Thangaratinam et al., 2012c), it is clear that services such as dietetics need to reach all women, particularly women with a BMI ≥25kg/m^2. As revealed in this study, HCPs had different views on routine weighing practices. Previous research indicated that while there are benefits to routine weighing, various challenges such as existing resources and time constraints need to be addressed in order to successfully implement the process of routine weighing of all women at every antenatal visit (Hasted, Stapleton, Beckmann, & Wilkinson, 2016). Furthermore, advice regarding the amount of weight to gain in pregnancy varied. This is perhaps not surprising as there is no formal guidance for appropriate GWG in Ireland. Previous research has demonstrated an evidence-practice gap relating to the provisional of clinical care of pregnant women with overweight and obesity (Wilkinson & Stapleton, 2012). Similarly, in the UK, HCPs were unsure about appropriate GWG in pregnancy (Olander et al., 2011). Evidence suggests that women who are not advised about appropriate GWG are more likely to gain outside the recommended ranges (Stotland et al., 2005). Therefore, further research and national guidance is needed to address divergent opinions about the benefits of weighting practices and lack of clarity on appropriate GWG to support standardised shared antenatal care.

Strengths and limitations

The inductive approach used in this qualitative study revealed the nuances and tensions involved in the management of pregnant women with overweight and obesity. The recruitment of a diverse sample of HCPs across settings, including hospital based HCPs and GPs with a range of experiences and specialities is a further strength of this study. Most of the HCPs were recruited from a limited geographical area and their perceptions and approach to weight management may not reflect those of HCPs working elsewhere. Variation in interview length occurred due to constraints and demands on participants' time.

Practice Implications

Hospital based HCPs and GPs are aware of the stigma around the topic of weight, particularly for women with a BMI ≥25kg/m^2. As part of encouraging healthy lifestyle choices, HCPs need to normalise the conversation around weight. Other health behaviours such as smoking and alcohol are considered more acceptable and easier to discuss (Heslehurst et al., 2011), therefore HCPs need to approach weight conversations in a similar manner. Training, education and skill development is required for HCPs to care effectively for these women. Lack of continuity of care undermines the consistency of weight management conversations and advice. Creating multidisciplinary teams or networks within the shared antenatal care setting would enhance and encourage knowledge sharing between HCPs allowing for effective communication between primary and secondary care. Furthermore, standardised approaches to weight management are needed and where possible, HCPs need to follow women during pregnancy to build rapport and ensure consistent information throughout. To address the sensitive nature of weight conversations, the most important question for HCPs is to ask how a patient feels about their weight in pregnancy. Negative reactions will alert HCPs that additional support may be required. Additionally, motivational interviewing could be used; this has been previously identified as an effective strategy when approaching sensitive issues such as obesity (Raymond & Clements, 2013).

5.6 Conclusion

Building rapport is necessary to deal with the sensitive nature of weight which requires consistent contact and guidance from HCPs. Roles and responsibilities for weight management within shared care needs to be clearer in this "*obesogenic environment*". By ensuring hospital based HCPs and GPS have the confidence, knowledge and opportunity to discuss weight and lifestyle factors with pregnant women, the women in turn may initiate or maintain healthy behaviours during pregnancy. Within shared care, evidence-based guidelines that support the consistent monitoring and management of weight during pregnancy could improve care and outcomes for these women.

6 STUDY 4: PHYSICAL ACTIVITY INTERVENTIONS DURING PREGNANCY

Physical activity interventions for overweight and obesity during pregnancy: A systematic review of the effectiveness and content of behaviour change interventions

C Flannery, M Fredrix, E Olander, F McAuliffe, M Byrne, PM Kearney

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6.1 Abstract

Background: The aim of this study was to identify and summarise the effectiveness of physical activity interventions on physical activity levels for pregnant women with overweight and obesity, with a specific emphasis on the behaviour change techniques (BCTs) employed.

Methods: A systematic review and meta-analysis of physical activity intervention studies using the PRISMA statement was conducted. Searches were conducted of eight databases in January 2018. Strict inclusion/exclusion criteria were employed. Primary outcome measures included change in physical activity levels, subjectively or objectively measured with physical fitness as a secondary outcome. The BCT taxonomy V1 was used to identify BCTs. Meta-analyses using random effect models assessed the intervention effects on physical activity. Other physical activity outcomes were summarised in a narrative synthesis.

Results: Of these, 11 studies provided data suitable for inclusion in a meta-analysis. Significant increases were found for metabolic equivalent (SMD 0.38 [0.07, 0.70], Z = 2.40 P = 0.02) and physical fitness (VO_2 max) (SMD 0.55 [0.34, 0.75], Z = 5.20 P = <0.001). Six additional studies were narratively described, five of which reported an increase in physical activity for the intervention group versus the control. ‘Self-monitoring of behaviour’ was the most frequently used BCTs (70.6%), with ‘social support’ unique to this population

Conclusion: This review revealed a slight increase in physical activity for pregnant women with overweight and obesity. However, these conclusions are tentative because of the poor methodological quality of the included studies. A range of BCTs clusters that could be used to help improve physical activity levels during pregnancy were identified, including: ‘goals and planning’, ‘feedback and monitoring’ and ‘shaping knowledge’ with ‘social support’ being unique to this population. Future studies should consider physical activity measures carefully so that studies can be meaningfully compared and intervention developers need to use recognised and standardised taxonomies so that BCTs can be accurately assessed.

6.2 Introduction

Overweight and obesity during pregnancy is an increasing public health concern. Overweight is defined as BMI ≥25 kg/m^2 and obesity is defined as a BMI ≥30 kg/m^2 which is assessed at the first antenatal consultation (Centre for Public Health Excellence at Nice National Collaborating Centre for Primary, 2006). Overweight and obesity is associated with a number of adverse maternal and neonatal outcomes including risk of gestational diabetes mellitus (GDM), pre-eclampsia, caesarean section, instrumental delivery and preterm delivery (Campbell et al., 2011; Marchi, Berg, Dencker, Olander, & Begley, 2015). Women with overweight and obesity are not only at increased risk of pregnancy complications but also weight retention in the longer term (Gore, Brown, & West, 2003; Hinton & Olson, 2001).

Physical activity has been identified as a modifiable lifestyle factor that could help prevent pregnancy complications, help with weight management and reduce the risk of GDM for women with overweight and obesity (The American College of Obstretricians and Gynecologists, Update 2015). Previous research has found that physically active pregnant women report better health than less physically active women as well as an increase in functional ability and a reduction in nausea, fatigue and stress (Artal & O'Toole, 2003; Nascimento, Surita, & Cecatti, 2012; RCOG, 2006b). Despite the significant health benefits, based on self-report, women tend to be less active in pregnancy (Evenson & Wen, 2010; Walsh et al., 2011). International guidelines recommend 30 minutes of daily moderate intensity physical activity for pregnant women (Health Service Executive, 2013; HSE/ICGP, 2013; RCOG, 2006a). A review which updated the latest evidence concerning exercise during pregnancy found that in the United States only 15.8% of women engaged in exercise during pregnancy (Evenson et al., 2004). Similarly low levels of physical activity have been reported in an Irish cohort of pregnant woman with only 21.5% of women meeting the current recommendations (Evenson et al., 2004; Nascimento et al., 2012; Walsh et al., 2011). Furthermore, a study examining lifestyle changes using the Pregnancy Risk Assessment Monitoring system (PRAMS) in Ireland found that adherence to physical activity guidelines of moderate intensity activity was low (12.3%) but was particularly low for pregnant women with overweight and obesity (6.4%) (O'Keeffe et al., 2016). Therefore, pregnant women with overweight and obesity should be encouraged to follow an exercise programme in order to get the best health outcomes for both mother and baby (Obstetricians & Gynecologists, 2013).

Behavioural change is complex and involves identifying effective and efficient techniques to bring about change (Jepson, Harris, Platt, & Tannahill, 2010). These techniques are called behaviour change techniques (BCTs) and are defined as 'an active component of an intervention designed to change behaviour' (Michie et al., 2013). In order to identify the intervention content or behavioural component of an intervention, the BCT taxonomy V1 was developed (Michie et al., 2013). The BCT Taxonomy V1 consisting of 93 different BCTs (16 categories) is a useful tool to extract the active components of successful and unsuccessful behaviour change interventions (Michie et al., 2013).

However reviews of lifestyle interventions during pregnancy are varied and results to date are conflicting (Asbee et al., 2009; Ronnberg & Nilsson, 2010; Sui et al., 2012). Many of the interventions promoting lifestyle changes throughout pregnancy are multidimensional incorporating a combination of diet and physical activity (Campbell et al., 2011; Dodd et al., 2010; Sui et al., 2012; Williams & French, 2011). These interventions tend to focus on medical or obstetric outcomes such as reducing excessive gestational weight gain (GWG) or GDM with less focus on the behavioural outcomes such as physical activity. Furthermore, the underlying behaviour change techniques (BCT) employed are often ignored. Without these underlying techniques it is difficult for researchers and clinicians to understand the context for the success or failure of the intervention and the key transferable intervention components (Asbee et al., 2009). Therefore, it is essential to identify which components and specific BCTs within these complex interventions are most effective to inform the development of future interventions.

According to a review by Currie et al (2013) which evaluated the content of physical activity interventions in pregnancy, interventions within the review were most effective when BCTs were employed and delivered face to face (Currie et al., 2013). However there is uncertainty around which underlying BCTs are most effective. Collins et al put forward two components that need to be explored in order to identify effective interventions. These are intervention programme (employed BCTs) and intervention delivery (intervention provider, format, setting, recipient, intensity, duration and fidelity of the intervention) (Collins et al., 2005). A review examining behaviour-change interventions for obese adults with additional risk factors or co-morbidities found suggestive evidence for an association between greater numbers of BCTs and greater weight loss (Dombrowski et al., 2012). Furthermore, a review examining intervention features of dietary and physical activity interventions for patients with type 2 diabetes revealed BCTs associated with clinically significant reductions in HbA_{1c} (Cradock et al., 2017). Previous systematic reviews in the area of pregnancy (Currie et al., 2013; Skouteris, Morris, Nagle, & Nankervis, 2014) have assessed intervention effectiveness including GWG (Asbee et al., 2009; Gardner, Wardle, Poston, & Croker, 2011; Ronnberg & Nilsson, 2010; Sui et al., 2012; Thangaratinam et al., 2012b) and GDM (Bain et al., 2015) but have not examined the intervention programme content itself.

BCTs have been retrospectively identified in a number of systematic reviews (Fredrix, McSharry, Flannery, Dinneen, & Byrne, 2018; Williams & French, 2011). The identification of optimal BCTs necessary for increasing physical activity in a healthy adult population found six important techniques including providing information on the likely consequences of specific behaviour, action planning, reinforcing effort or progress, providing instructions, facilitative social comparison and time management (Williams & French, 2011). However the techniques associated with increasing physical activity for adults' with obesity such as 'teach to use prompts/cues', 'prompt practice' or 'prompt rewards' were different. Thus, to develop effective physical activity interventions it may be important to consider tailoring intervention techniques to the target population (Olander et al., 2013). In pregnancy, using the most up-to-date BCT taxonomy, Currie et al (2013) identified the most common BCTs for normal weight pregnant women such as 'goal setting', 'feedback and planning', 'repetition and substitution', 'shaping knowledge' and 'comparison of behaviours' (Currie et al., 2013). The significance of these BCTs may be different for pregnant women compared to non-pregnant women since pregnancy is a unique time where women may be more receptive to improving health behaviours (Lawlor & Chaturvedi, 2006). Furthermore, the value of these techniques is also likely to depend on the weight profile of the pregnant population and successful BCTs may differ for pregnant women with overweight and obesity compared to pregnant women with a normal BMI (Hui et al., 2006; Jeffries et al., 2009; Phelan et al., 2011; Polley et al., 2002).

Therefore, the aims of this systematic review was to identify and summarise the effectiveness of physical activity interventions for pregnant women with overweight and obesity on physical activity levels and identify which BCTs were most frequently used in these interventions and determine which were most effective in improving physical activity levels.

6.3 Methods

This systematic review and meta-analysis were reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009). The review protocol was pre-registered with the International Prospective Register of Systematic Reviews (PROSPERO) database (CRD42016033423) (Appendix C).

Eligibility criteria

Types of studies

Eligible study designs included pilot randomised controlled trials, randomised control trials (RCTs), non-randomised control trials, quasi RCTs, and quasi-experimental studies of physical activity interventions, aimed at maintaining or increasing physical activity levels conducted either in a health care setting, community setting, online or individual's home. Furthermore, for inclusion, all interventions had to target pregnant women with overweight and obesity with a body mass index (BMI) ≥25kg/m^2, have at least one component focusing explicitly on physical activity, and include a discernible BCT in the intervention description. Control groups were classified as a comparator intervention or usual care if stated. Usual care would indicate standard antenatal care for pregnant women. Studies were included regardless of treatment intensity, duration or mode of delivery of the intervention. Only studies published in English were included. Studies published in the grey literature (non-peer reviewed or without scientific credibility) were excluded.

Types of participants

Participants included pregnant women with overweight and obesity with a pre-pregnancy or early pregnancy BMI ≥25kg/m^2 and singleton pregnancies.

Types of outcome(s) measures

Studies were included that reported any of the following primary outcome measures: change in physical activity levels subjectively (e.g., self-report) or objectively measured (e.g., step count) at baseline and post intervention. Secondary outcomes include studies that reported VO_2 max as a measure of physical fitness.

Information Sources

Searches

MEDLINE, EMBASE, PsychInfo, CINAHL, Cochrane Library, PEDro, SportDiscus and PubMed databases were searched from inception. The searches were undertaken in January 2018**.** The search strategy for each database is available in (Appendix C, Table 27). Phrases and MESH headings for each component of the population, intervention, comparator and outcome framework (PICO), were combined using OR and then using AND (maternal, pregnancy, pregnant woman, expectant mothers; lifestyle, lifestyle modification, health promotion, behaviour change, physical activity, exercise, fitness, activities of daily living, human activities, group exercise, randomised controlled trial, intervention trials and clinical trials; standard care; physical activity, gestational weight gain and gestational diabetes). Manual searches of reference lists were conducted on all eligible articles following screening.

Study selection

One author (CF) conducted the searches and imported citations in to a reference management software package (Endnote version 7). Duplicates were removed. In the first screening stage, all titles of the search results were examined and irrelevant titles were removed if they did not meet the inclusion criteria. In the second stage, title and abstracts were screened. Ten percent of title and abstracts were double screened by authors (MB, EO, PK and FMA). Any discrepancies were resolved by consensus. Cohen's kappa (*k)* was calculated to determine the extent of interrater agreement (Cohen, 1960; Landis & Koch, 1977). In the third stage of the screening process, relevant articles were obtained in full and assessed against the inclusion and study quality criteria. Full text screening was conducted by (CF) and checks were made by two second reviewers (MB and PK); discrepancies were resolved by consensus. The number of articles at each stage can be seen in the PRISMA flow chart (Figure 9).

Data extraction

A data form was developed based on the Workgroup for Intervention Development and Evaluation Research (WIDER) framework for the scientific reporting of behaviour change interventions (Appendix C, Table 28) (Albrecht et al., 2013). Data from each included study were extracted by one reviewer (CF) and independently checked by two others (MB and PK). In case of discrepancies, consensus was reached through discussion. Extracted data included detailed description of the interventions (study design, participant information, setting, details of the intervention, sample size, mode of delivery, type of contact and setting) and BCTs included in the intervention. Physical activity measures for baseline, pre and post intervention, where possible, were extracted from studies or calculated using reported means, standard deviations, and sample sizes at baseline, post-intervention.

Coding of BCTs

The BCT taxonomy V1 (Michie et al., 2013) was used to identify the behavioural components of the intervention within each included study. This validated taxonomy consists of 93 different BCTs divided into 16 categories. A BCT was only coded when it was explicitly mentioned in the intervention or supporting materials (study protocols). The BCT coding was completed independently by two reviewers (CF and MF) who underwent training in BCT coding using the BCT taxonomy. Inter-rater reliability was calculated (Cohen, 1960; Landis & Koch, 1977) and discrepancies were discussed until 100% agreement was achieved.

Quality assessment

Following the intensive screening process only RCTs were included, therefore, the validity of each included study was assessed using the Cochrane Collaboration's tool for assessing risk of bias (Green, 2011). The validity of each included study was assessed using the Cochrane Collaboration's tool for assessing risk of bias (Green, 2011). This tool assesses key methodological domains; sequence generation, allocation concealment, blinding of participants, personnel and outcome assessors, incomplete outcome data, selective outcome reporting, other sources of bias (Green, 2011). The risk of bias was assessed by one reviewer (CF) and in the case of discrepancies consensus was reached through discussion with two authors (MB and PK).

Strategy for data synthesis

Effect of the intervention

Results from the included studies were combined in a meta-analysis if sufficient outcome data were available from at least two studies. When an intervention reported data at several time points during pregnancy, the last measure before birth was used. Continuous data were summarized as mean difference and standard deviations (SD). Where possible, means and SD were calculated from median and interquartile range (Hozo et al., 2005). Within the meta-analysis, primary and secondary physical activity outcomes reported on the same scale (e.g. MET, Steps and VO2 max) were combined using standardised mean differences (SMD). For all effect sizes, 95% Confidence Intervals (CI) were used and results were pooled using a random effects model (inverse-variance approach based on weighted SMDs) using RevMan Software (version 5.3: Review Manger). Furthermore, the I^2 statistic was used to indicate the percentage of total variation (Green, 2011). If data was not available for pooling outcomes, all other physical activity outcomes measures were combined in a narrative synthesis. To test the robustness of the findings, risk of publication bias were conducted using Comprehensive Meta-Analysis (CMA) software (version 3). Funnel plots were generated and a test for statistical significance for funnel plot asymmetry was performed using Eggers test (Egger, Smith, Schneider, & Minder, 1997).

BCTs

A BCT was only coded when there was clear evidence of its inclusion in the intervention and it was identified as present by both reviewers. The total number of BCTs was recorded and the frequency of identified BCTs was quantified. Subgroup analysis was selected as a method to examine the effectiveness of different BCTs on outcomes included in the meta-analysis. Subgroup analysis would only be conducted if a meta-analysis was conducted with 10 or more studies. Pearson's r correlation coefficient was used to investigate the relationship between the number of BCTs used and the outcome effect sizes.

6.4 Results

Study selection

From 8024 studies, 17 studies were included (Figure 9), describing 3 pilot randomised controlled trials (Callaway et al., 2010; Hawkins et al., 2015; Kong, Campbell, Foster, Peterson, & Lanningham-Foster, 2014) and 14 randomised controlled trials (Guelinckx et al., 2010; Koivusalo et al., 2016; Nascimento et al., 2011; Ong et al., 2009; Oostdam et al., 2012; Santos et al., 2005; Vinter et al., 2011) of which 2 were multicentre (Dodd et al., 2014; Poston et al., 2015), 2 were prospective (Bruno et al., 2017; Renault et al., 2014), 2 were parallel (Garnaes, Morkved, Salvesen, & Moholdt, 2016; Seneviratne et al., 2016) and 1 was a nested randomised controlled trial (Szmeja et al., 2014). Cohen's kappa (*k)* (McHugh, 2012) was calculated to determine the extent of inter-rater agreement during the screening phase and a substantial agreement was reached (k =0.63). All disagreements were resolved through discussion with all co-authors. The total number of participants included in all studies was 6976, ranging from 12 (Ong et al., 2009) to 1924 (Dodd et al., 2014) in individual studies.

Health outcomes measured in the interventions included gestational weight gain, fasting insulin, fasting glucose, gestational diabetes, gestational age (wks.), and birth weight. Eight studies were investigations targeting physical activity promotion alone (Callaway et al., 2010; Garnaes et al., 2016; Kong et al., 2014; Nascimento et al., 2011; Ong et al., 2009; Oostdam et al., 2012; Santos et al., 2005; Seneviratne et al., 2016) while nine others were of interventions targeting diet and physical activity (Bruno et al., 2017; Dodd et al., 2014; Guelinckx et al., 2010; Hawkins et al., 2015; Koivusalo et al., 2016; Poston et al., 2015; Renault et al., 2014; Szmeja et al., 2014; Vinter et al., 2011). Thirteen studies described their control groups as receiving standard routine antenatal care. There was no clear definition of standard antenatal care in these studies. Four studies described their control group as those who were not provided with the intervention (Seneviratne et al., 2016), those who were not provided with physical activity recommendations or restricted from physical activity participation (Kong et al., 2014; Vinter et al., 2011). The final study compared the intervention with a stretching group which included relaxation (respiratory exercises and light stretching)(Santos et al., 2005).

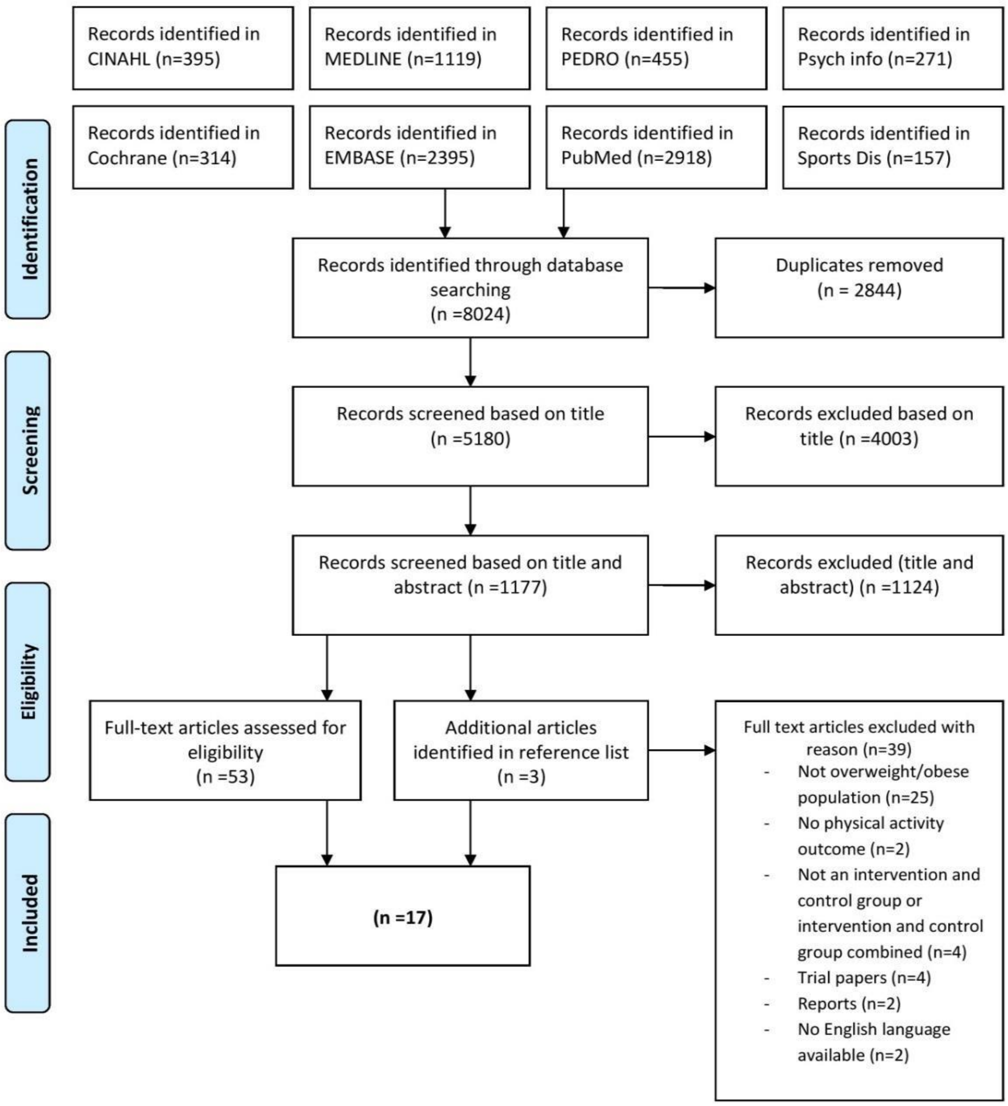


Figure 9: PRISMA flow diagram

Characteristics of included studies

Studies were conducted in Australia (Callaway et al., 2010; Dodd et al., 2014; Ong et al., 2009; Szmeja et al., 2014), the Netherlands (Oostdam et al., 2012), the USA (Hawkins et al., 2015; Kong et al., 2014), Brazil (Nascimento et al., 2011; Santos et al., 2005), New Zealand (Seneviratne et al., 2016), the UK (Poston et al., 2015), Italy (Bruno et al., 2017), Finland (Koivusalo et al., 2016), Denmark (Renault et al., 2014; Vinter et al., 2011), Belgium (Guelinckx et al., 2010) and Norway (Garnaes et al., 2016). Ten studies were interventions that targeted pregnant women with overweight and obesity (Bruno et al., 2017; Dodd et al., 2014; Garnaes et al., 2016; Hawkins et al., 2015; Kong et al., 2014; Nascimento et al., 2011; Oostdam et al., 2012; Santos et al., 2005; Seneviratne et al., 2016; Szmeja et al., 2014) while seven studies focused on obese pregnant women only (Callaway et al., 2010; Guelinckx et al., 2010; Koivusalo et al., 2016; Ong et al., 2009; Poston et al., 2015; Renault et al., 2014; Vinter et al., 2011) (See Table 9).

Intervention characteristics

Intervention duration ranged between 8 and 24 weeks. An explicit theoretical basis was mentioned in 5 out of the 17 studies, including stage theories of health decision making, behavioural modification, the trans-theoretical model, social cognitive theory and control theory (Dodd et al., 2014; Guelinckx et al., 2010; Hawkins et al., 2015; Poston et al., 2015; Szmeja et al., 2014). Most of the interventions were based in clinical settings (Bruno et al., 2017; Callaway et al., 2010; Dodd et al., 2014; Garnaes et al., 2016; Guelinckx et al., 2010; Hawkins et al., 2015; Koivusalo et al., 2016; Oostdam et al., 2012; Poston et al., 2015; Renault et al., 2014; Santos et al., 2005; Szmeja et al., 2014; Vinter et al., 2011), in the participant’s home (Ong et al., 2009; Seneviratne et al., 2016) or in a combination of both (Kong et al., 2014; Nascimento et al., 2011). Interventions were mostly delivered face-to-face and or via phone contact and were commonly provided by a physiotherapist, nutritionist/dieticians, study researchers, health educators or other health care professionals. The intensity of interventions ranged from one contact moment to 17 contact moments with an average of 4.2 contact moments in the interventions. Table 10 provide details on the intervention components and BCTs in the included studies.

Table 9: Characteristics of included studies

Author & Year	Country	Study design	Age	BMI	Gestation	Pregnancy type	Other risk factors	Intervention detail (brief description, comparison)	Type of PA measure	PA outcome measure
Callaway et al 2010	**Australia**	**Pilot RCT**	**Aged 18-45**	**BMI ≥ 30**	**Not specified**	**Not specified**	**Not specified**	**Intervention group: individualized exercise program with an energy expenditure EE goal of 900 kcal/ week *Comparison:*** routine obstetric care	**Self-report**	**Pregnancy Physical Activity Questionnaire (PPAQ) - MET (hr./week)**
Oostdam et al 2012	**Amsterdam**	**RCT**	**Not specified**	**BMI ≥25 or ≥30**	**Not specified**	**Not specified**	**At least one: macrosomia, history of GDM or relative with T2D**	**Exercise programme consisting of aerobic + strength exercises aimed top control blood glucose levels. *Comparison:*** received normal care from obstetricians and or midwives	**Objective**	**ActiTrainer accelerometer ActiGraph accelerometer - Total minutes per week of PA + MET cut -off values**
Nascimento et al 2011	**Brazil**	**RCT**	**Not specified**	**BMI 26-29**	**14-24 weeks**	**Not specified**	**Not specified**	**Two components: The exercise protocol consisting of light-intensity to moderate-intensity exercises + home exercise counselling. *Comparison:*** no physical activity counselling, received routine prenatal care	**Self-report**	**Women recorded the type + minutes of exercise in an exercise journal**
Kai Ling Kong et al 2014	**USA**	**Pilot RCT**	**Aged 18-45**	**BMI > 25 or >30**	**Not specified**	**Singleton**	**Non-smoker, no prior history of chronic disease**	**Unsupervised walking program - Walking (150 min/week of moderate PA during pregnancy). *Comparison:*** no physical activity recommendations, no restrictions from physical activity participation	**Objective**	**StepWatch Activity Monitor (SAM) accelerometer - using step data (counts)**
Seneviratne et al 2016	**Auckland New Zealand**	**Two arm parallel RCT**	**Aged 18-40**	**BMI ≥25**	**<20 weeks**	**Singleton**	**Not specified**	**Structured home-based exercise programme using magnetic stationary bicycles. *Comparison:*** no intervention or heart rate monitor	**Objective**	**Heart rate monitor - duration and intensity of cycling**

Table 9: Characteristics of included studies (continued)

Ong et al 2009	**Western Australia**	**RCT**	**Aged 30 (±4years)**	**BMI ≥30**	**Not specified**	**Singleton**	**Sedentary women, a normal 18 week scan**	**Home-based supervised exercise using an upright stationary cycle ergometer that each participant kept in their home during the intervention.** ***Comparison:*** continued with their usual daily activities while receiving regular antenatal care	**Objective and self-report**	**Aerobic Power Index sub maximum test and Pregnancy PA questionnaire**
Santos et al 2005	**Brazil**	**RCT**	**Aged ≥20**	**BMI ≥25**	**Not specified**	**Not specified**	**Non-smoking**	**Supervised PA consisting of warm up, heart rate monitored activity, upper and lower limbs, stretching and relaxation.** ***Comparison:*** participated in once weekly sessions that included relaxation (respiratory exercises and light stretching (no aerobic or weight resistance) Participates were neither encourage nor discouraged to exercise	**Objective and self-report**	**Physical activity questionnaire) and the Aerobic Power Index sub maximum test- Vo2max**
Garnaes et al 2016	**Norway**	**Single centre, parallel group RCT**	**Aged ≥18**	**BMI ≥28**	**<18 weeks**	**Singleton**	**Live fetus at 11-14 week ultrasound scan**	**Supervised exercise consisting of treadmill walking/jogging for 35 minutes (endurance) and resistance training for large muscle groups and the pelvic floor muscles.** ***Comparison:*** ordinary maternity care by their midwife, GP and or obstetrician	**Self-report**	**PA questionnaire - Frequency, duration and intensity of weekly PA**
Dodd et al 2014	**South Australia**	**Multicentre RCT**	**Not specified**	**BMI ≥25**	**Between 10-20 weeks**	**Singleton**	**Not specified**	**Lifestyle Advice consisted of dietary + lifestyle intervention including dietary, PA and behavioural strategies + goal setting.** ***Comparison****:* continued pregnancy care according to local hospital guidelines	**Self-report**	**Health-enhancing PA (SQUASH) - MET (min/week)**

Table 9: Characteristics of included studies (continued)

Guelinckx et al 2010	**Belgium**	**RCT**	**Not specified**	**BMI >29**	**<15 weeks**	**Not specified**	**White**	**Passive group: brochure consisting of diet and PA advice + tips to limit weight gain. Active group: received the same brochure and was actively counselled. Techniques of behavioural modification were used. *Comparison:*** routine perinatal care	**Self-report**	**Baecke questionnaire - Total score for PA from a minimum of 3 to a maximum of 15**
Hawkins et al 2015	**Western Massachusetts**	**Pilot RCT**	**Aged 18-40**	**BMI ≥25**	**<18 weeks**	**Not specified**	**Hispanic women, participating in <30minutes PA per week**	**Achieve PA guidelines through increasing walking and developing a more active lifestyle. Dietary component: decrease foods high in saturated fat and increase fibre. *Comparison:*** standard care	**Self-report**	**Pregnancy PA Questionnaire (PPAQ) - average MET (h/week)**
Koivusalo et al 2016	**Finland**	**RCT**	**Aged ≥18**	**BMI ≥30**	**<20 weeks**	**Not specified**	**History of GDM**	**Dietary and PA counselling (minimum of 30 minutes of moderate intensity exercise and to adopt an overall active lifestyle). *Comparison:*** received general antenatal care, information leaflets provided by the local antenatal clinics.	**Self-report**	**Food frequency and PA questionnaire - Self report time spent weekly on PA**
Poston et al 2015	**UK**	**Multicentre RCT**	**Aged >16**	**BMI ≥30**	**Between 15-18 weeks (+6days)**	**Singleton**	**Not specified**	**SMART goals, advice on self-monitoring, problem solving. Handbook about the intervention, theory and recommended food and PA. DVD of an exercise regimen. *Comparison:*** routine antenatal appointments at their trial centre in accordance with local practice	**Self-report**	**PA questionnaire (IPAQ) - MET (min/week)**

Table 9: Characteristics of included studies (continued)

Renault et al 2014	**Copenhagen**	**Prospective RCT**	**Aged >18**	**BMI ≥30**	**Between 11-14 weeks**	**Singleton**	**Read and speak Danish**	**(PA plus D and PA only) individually advised and encouraged to increase PA aiming at a daily step count of 11000 steps. The diet intervention consisted of contact with an experienced dietician. *Comparison:*** received usual hospital standard regimen for obese pregnant women	**Objective**	**Pedometer - Daily steps were registered on 7 consecutive days every 4 weeks**
Szmeja et al 2014	**South Australia**	**Nested RCT**	**Not specified**	**BMI ≥25**	**Between 10-20 weeks**	**Singleton**	**Not specified**	**Lifestyle advice group from (LIMIT) receive DVD or standard materials. Set goals. Received pregnancy book with nutrition + exercise in pregnancy book. *Comparison:*** received the standard written materials and consultations	**Self-report**	**Metabolic equivalent task units - MET (min/week)**
***Vinter et al 2011**	**Denmark**	**RCT**	**Aged 18-40**	**BMI 30-45**	**Not specified**	**Not specified**	**Not specified**	**Two components: dietary counselling and PA. The aim was to limit GWG to 5kg. Energy requirement was estimated and PA (30-60) min daily. Women also had free full time membership in a fitness centre. *Comparison:*** received information about the study but no intervention	**Objective**	**Aerobic Power Index submaximal aerobic exercise - VO2max**
***Bruno et al 2017**	**Italy**	**Prospective RCT**	**Aged >18**	**BMI ≥25**	**Not specified**	**Singleton**	**Not specified**	**PA intervention to develop a more active lifestyle (30mins of PA at least 3 times per week). *Comparison:*** control group received a nutritional booklet. All women the control group received antenatal care	**Objective**	**Pedometer - Assess the number of steps and the duration of PA**

RCT, randomised controlled trial; MET, metabolic equivalent; VO2, oxygen output; PA, Physical activity; EE, energy expenditure; D, Dietary; BMI, body mass index; IPAQ, international physical activity questionnaire; PPAQ, pregnancy physical activity questionnaire; GDM, gestational diabetes mellitus; T2D, type 2 diabetes *Significant reduction in maternal outcomes such as gestational weight gain and hypertension, and neonatal outcomes such as birth weight

Table 10: Intervention characteristics

Author & Year	Theory	Contact type	Contact intensity	Delivery	Setting	Type	Intervention duration*	BCTs
Callaway et al 2010	Not present	Face-to-face (individual) + via phone	6 face to face	Exercise physiologists; Dietician; Physiotherapists; Midwife	Clinical setting	PA	24 weeks	1.2 Problem solving 1.3 Goal setting outcome 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 4.1 Instruction on how to perform behaviour 5.1 Information about health consequence
Oostdam et al 2012	Not present	Face-to-face (individual)	At least 1 face to face	Physiotherapist	Clinical setting + midwifery practices	PA	17 weeks (+12 weeks postpartum follow up)	3.1 Social Support (Unspecified) 4.1 Instruction on how to perform behaviour 5.1 Information about health consequence 8.1 Behavioural practice/rehearsal
Nascimento et al 2011	Not present	Face-to-face (individual + group)	8 face to face	Physical therapist	Clinical setting + participants home	PA	19 weeks	2.3 Self-monitoring of behaviour 3.1 Social Support (Unspecified) 4.1 Instruction on how to perform behaviour 5.1 Information about health consequence 8.1 Behavioural practice/rehearsal
Kai Ling et al 2014	Not present	Face-to-face (individual)	3 face to face	Study coordinator	Clinical setting + participants home	PA	20 weeks	2.3 Self-monitoring of behaviour 4.1 Instruction on how to perform behaviour 12.5 Adding objects to the environment
Seneviratne et al 2016	Not present	Face-to-face (individual)	1 face to face	Exercise physiologist	Participants home	PA	15 weeks	1.1 Goal setting (behaviour) 4.1 Instruction on how to perform behaviour 12.5 Adding objects to the environment
Ong et al 2009	Not present	Not specified	no mention of contact with study team	Not specified	Participants home	PA	10 weeks	12.5 Adding objects to the environment

Table 10: Intervention characteristics (continued)

Santos et al 2005	Not present	Face-to-face (individual)	no mention of contact with study team	Not specified	Clinical setting	PA	12 weeks	8.1 Behavioural practice/rehearsal
Garnaes et al 2016	Not present	Face-to-face (individual or group)	At least 1 face to face	Physical therapist	Clinical setting	PA	19 weeks	2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcome(s) of behaviour 3.1 Social Support (Unspecified) 4.1 Instruction on how to perform behaviour 8.1 Behavioural practice/rehearsal
Dodd et al 2014	Stage theories of health decision making	Face-to-face (individual) + via phone	3 phone calls; 1 face to face	Dietician; Research assistants	Clinical setting	PA + diet	20 weeks (+ 16 weeks post-partum follow up)	1.2 Problem solving 1.3 Goal setting outcome 2.3 Self-monitoring of behaviour 4.1 Instruction on how to perform behaviour 5.1 Information about health consequence
Guelinckx et al 2010	Techniques of behavioural modification	Face-to-face (group)	3 group sessions	Nutritionist	Clinical setting	PA + diet	17 weeks	4.1 Instruction on how to perform behaviour 6.1 Demonstration of the behaviour
Hawkins et al 2015	The Trans theoretical Model and Social Cognitive Theory	Face-to-face (individual) + via phone	6 face to face; 5 phone calls	Health educators	Clinical setting	PA + diet	24 weeks (+ 6 weeks post-partum follow up)	1.2 Problem solving 1.3 Goal setting outcome 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social Support (Unspecified)
Koivusalo et al 2016	Not present	Face-to-face (individual + group)	3 face to face; group visits	Study nurse; Nutritionist	Clinical setting	PA + diet	22 weeks	1.1 Goal setting (behaviour) 1.4 Action Planning 2.3 Self-monitoring of behaviour

Table 10: Intervention characteristics (continued)

Poston et al 2015	Control theory and elements of social cognitive theory	Face-to-face (individual + group)	8 face to face	Health trainer	Clinical setting	PA + diet	16 weeks (+ 24 week post-partum follow up)	1.2 Problem solving 1.3 Goal setting (outcome) 1.7 Review outcome goals 2.3 Self-monitoring of behaviour 3.1 Social Support (Unspecified) 4.1 Instruction on how to perform behaviour 5.1 Information about health consequence 6.1 Demonstration of the behaviour 6.2 Social comparison 8.1 Behavioural practice/rehearsal
Renault et al 2014	Not present	Face-to-face (individual) + via phone	6 face to face; 6 follow up calls	Dietician	Clinical setting	PA + diet	22 weeks	1.1 Goal setting (behaviour) 2.3 Self-monitoring of behaviour 3.1 Social Support (Unspecified)
Szmeja et al 2014	Stage theories of health decision making	Face-to-face (individual) + via phone	2 face to face; 3 calls	Research dietician; Trained research assistants	Clinical setting	PA + diet	8 weeks	1.2 Problem solving 1.3 Goal setting (outcome) 2.3 Self-monitoring of behaviour 4.1 Instruction on how to perform behaviour 5.1 Information about health consequence
Vinter et al 2011	Not present	Face-to-face (individual)	4 face to face	Dieticians; physiotherapists	Clinical setting	PA + diet	21 weeks	1.3 Goal setting (outcome) 2.3 Self-monitoring of behaviour 3.1 Social Support (Unspecified) 4.1 Instruction on how to perform behaviour 8.1 Behavioural practice/rehearsal

Table 10: Intervention characteristics (continued)

Bruno et al 2017	**Not present**	**Face-to-face (individual)**	**At least 1 face to face**	**Gynaecologist; Dietician**	**Clinical setting**	**PA + diet**	**20 weeks**	**1.5 Review behaviour goal(s)** **1.7 Review outcome goal(s)** **2.3 Self-monitoring of behaviour** **4.1 Instruction on how to perform behaviour**

PA, physical activity; BCT, behaviour change technique, *full intervention length

Quality of included studies

Overall methodological quality was poor. Three studies were rated as having high potential risk of bias. Nine studies inadequately reported methodological quality indicators (e.g. studies lacked information on randomisation, allocation and outcome assessment concealment and inadequate missing data handling, see Appendix C, Table 26). For most studies, there was inadequate information to make judgements about methodological quality and the risk of bias. Five studies were rated as low risk as they provided adequate information; however, four of these uses self-report measure for physical activity. Furthermore, overall, blinding (performance bias and detection bias) was considered to have the highest risk as most studies failed to document the blinding procedures. A summary of the risk of bias for all 17 studies is shown in Figure 10 (Appendix C, Figure 13).

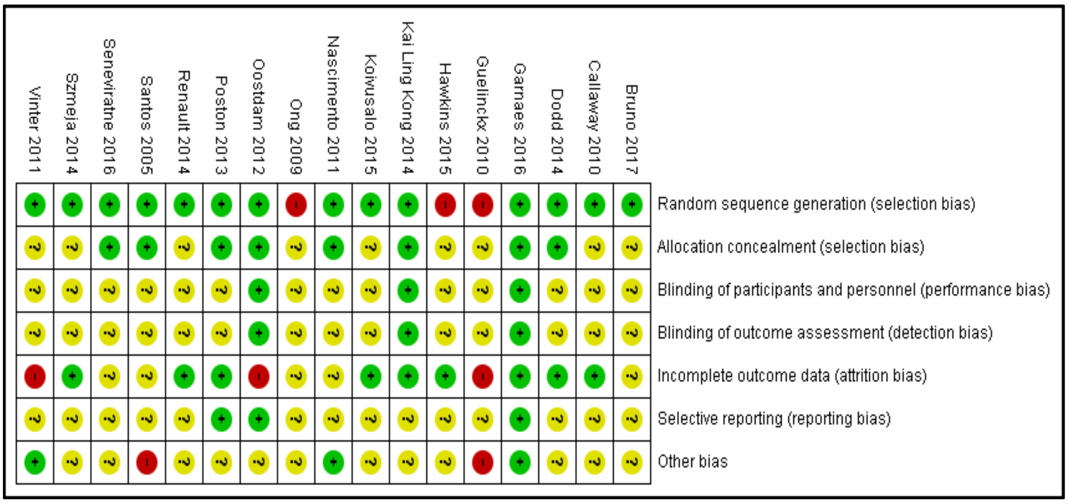


Figure 10: Risk of bias

Publication bias

For MET min per week the p-value for Eggers test was 0.27 which suggests that publication bias could not be detected. The funnel plot can be seen in Appendix C, Figure 14. Eggers test and funnel plots were not conducted for step count data or VO_2 max as insufficient data was available.

Effectiveness of the intervention

Physical activity outcomes

A wide variety of measures was used to assess physical activity in each of the included papers. Seven trials assessed physical activity objectively: three trials used pedometers deriving step-count (Bruno et al., 2017; Kong et al., 2014; Renault et al., 2014), one trial used an accelerometer to create metabolic equivalent (MET) (Oostdam et al., 2012), heart rate monitor data was collected to identify the duration and intensity of physical activity (Seneviratne et al., 2016) and VO_2max was used as an indicator for physical fitness in two studies (Santos et al., 2005; Vinter et al., 2011). Of the 17 included papers, 11 provided data suitable for inclusion in a meta-analysis (Bruno et al., 2017; Callaway et al., 2010; Dodd et al., 2014; Hawkins et al., 2015; Kong et al., 2014; Oostdam et al., 2012; Poston et al., 2015; Renault et al., 2014; Santos et al., 2005; Szmeja et al., 2014; Vinter et al., 2011) (Figure 11).

Primary physical activity outcomes

Metabolic equivalent (MET) - Minutes per week

Physical activity expressed in METS represents the metabolic equivalent intensity levels for activities with moderate intensity activity classified as 3-5 METS. Therefore 150 minutes of moderate intensity physical activity is equivalent to 450-750 MET/ minutes per week (Ainsworth et al., 2000; Medicine, 2013). Six studies comparing interventions using METs minutes per week to a control group were combined in a meta-analysis (Callaway et al., 2010; Dodd et al., 2014; Hawkins et al., 2015; Oostdam et al., 2012; Poston et al., 2015; Szmeja et al., 2014). A meta-analysis using standardised mean differences at follow up demonstrated a significant increase in MET minutes per week (SMD 0.38 [0.07, 0.70], Z = 2.40 P = 0.02). However the studies were significantly heterogeneous (χ^2 = 91.98, d.f. = 5 [P <0.0001), I^2 = 95%.

Step count data

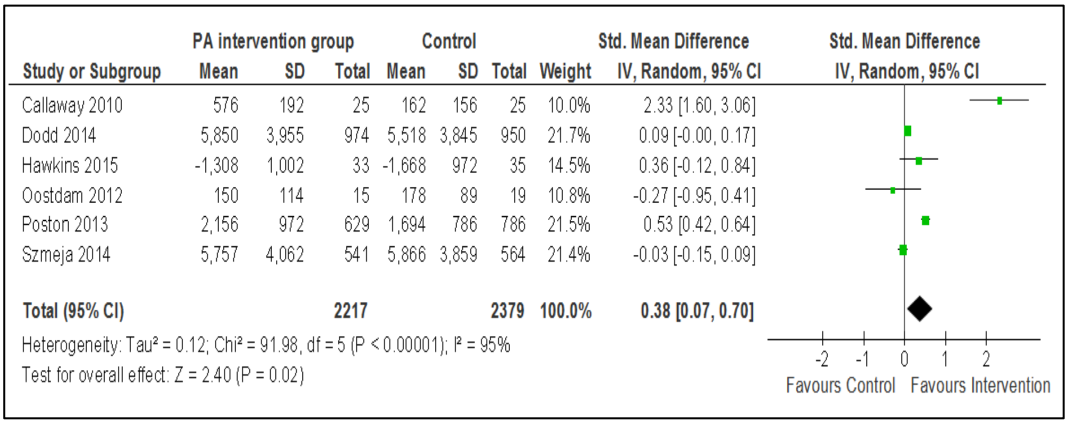
Three studies comparing physical activity interventions to a control group that used step count data at follow up were combined. One of these studies included multiple intervention arms which were combined, however participants in the control group of this study did not wear pedometers so step count data was not available for comparison (Renault et al., 2014). The studies were significantly heterogeneous (χ^2 =6.36, d.f. = 1 [P = 0.01), I^2 = 84% and demonstrated no significant difference in physical activity steps per day between the intervention and control groups at follow up (SMD -0.08 [-1.01, 0.85], Z = 0.16 P= 0.87).

Secondary physical activity outcome

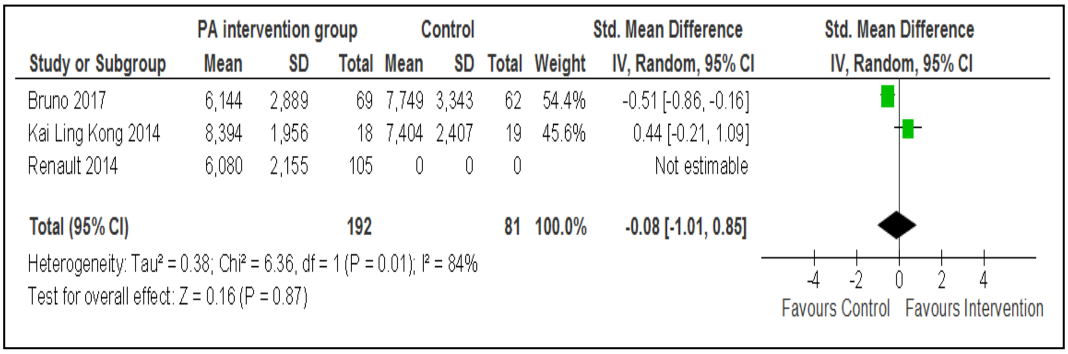
VO_2 Max measures of physical fitness

Two studies compared VO_2 Max to measure the amount of oxygen used during exercise in order to assess physical fitness compared to control at follow up. The studies were homogenous (χ^2 = 0.72, d.f. = 1 [P= 0.40], I^2 = 0%) and demonstrated significantly greater physical fitness in the intervention group compared to the control group (SMD 0.55 [0.34, 0.75], Z = 5.20 P = <0.001).

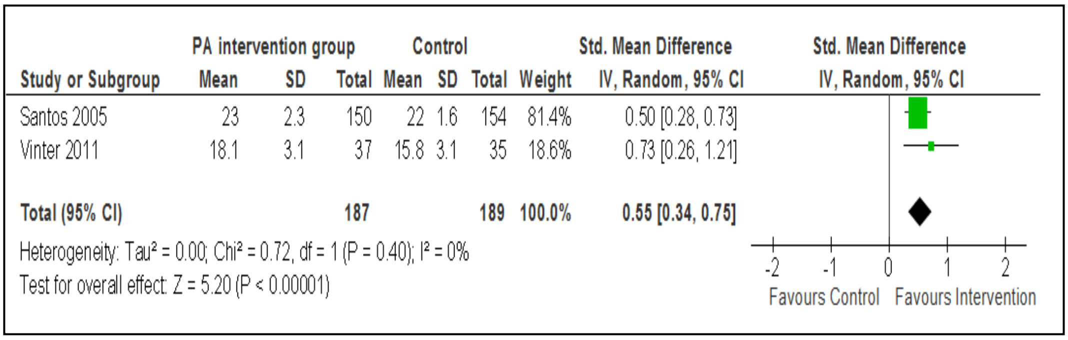
MET m/wk



Steps Count Data



VO_2 max



MET m/wk., Metabolic Equivalent minutes per week; Steps, Steps per day; VO_2 max, measure of physical fitness (oxygen used during exercise)

Figure 11: Meta-analysis of effect of interventions on physical activity outcomes

Other physical activity interventions

Six additional trials that were not included in the meta-analyses due to insufficient data and different outcome measures reporting varying intervention effects at follow up. Five of these studies reported an increase in physical activity or physical fitness for women in the intervention group compared to control (Garnaes et al., 2016; Koivusalo et al., 2016; Nascimento et al., 2011; Ong et al., 2009; Seneviratne et al., 2016). Women who received diet and physical activity counselling increased their median weekly leisure time physical activity by 15 minutes (95% [C1 1-29mins] while the physical activity of women in the control group remained unchanged (P=0.17 unadjusted)(Koivusalo et al., 2016). Furthermore, in two home based interventions using stationary bicycles, women in the intervention group improved their aerobic fitness, either by increasing the test time taken to reach target heart rate of 150 bpm or (+48.0; P =0.019)(Seneviratne et al., 2016) or indicated by higher cycling power output 75% HR_{max} (P = 0.064) (Ong et al., 2009) compared to the control groups. A supervised exercise programme consisting of treadmill walking and resistance training found that the proportion of women reporting regular exercise training in late pregnancy was significantly higher in the exercise group than in the control group: 77% and 23% respectively (P<0.01)(Garnaes et al., 2016). However, one study that consisted of two intervention groups (passive consisting of brochure and physical activity advice; active group consisting of the same but included active counselling) found that physical activity significantly decreased for women in their 3rd trimester (p=0.002)(Guelinckx et al., 2010).

Effect on health outcomes

Some interventions found a slight reduction in maternal and neonatal outcomes such as gestational weight gain (Hawkins et al., 2015; Koivusalo et al., 2016; Renault et al., 2014; Vinter et al., 2011), hypertension and infant birth weight (Bruno et al., 2017) and the incidence of GDM (Bruno et al., 2017).

Behaviour change techniques

Presence of BCTs

A total of 16 different BCTs were applied within the 17 intervention studies, ranging between 1 and 10 in each study (Table 10). 'Self-monitoring of behaviour' and 'Instruction on how to perform the behaviour' were the most frequently used across the interventions and was identified in 12 out of the 17 studies (70.6%). 'Social support (unspecified)' was used in 7 out of the 17 interventions (41.2%), an average 11.1 times within each intervention (Table 11). 'Social support (unspecified)' and 'Instruction on how to perform the behaviour' were identified in one comparator group which consisted of once-weekly sessions of relaxation, respiratory exercises and light stretching and focus group discussions concerning maternity (Santos et al., 2005). Inter-rater reliability was calculated by a chance-corrected kappa (k=0.65) indicating substantial agreement.

Table 11: Frequencies of behaviour change techniques used in the interventions

Groups	BCT	N	%	Average # of time BCT is used within each intervention
Goals and planning	**1.1 Goal setting (behaviour)**	**3**	**17.6**	**7.7**
	1.2 Problem solving	**5**	**29.4**	**6.2**
	1.3 Goal setting outcome	**6**	**35.3**	**4.8**
	1.4 Action Planning	**1**	**5.9**	**1**
	1.5 Review behavioural goals	**1**	**5.9**	**4**
	1.7 Review outcome goals	**1**	**5.9**	**5.5**
Feedback and monitoring	**2.2 Feedback on behaviour**	**2**	**11.8**	**8.5**
	2.3 Self-monitoring of behaviour	**12**	**70.6**	**4.3**
	2.4 Self-monitoring of outcome of behaviour	**1**	**5.9**	**1**
Social support	**3.1 Social Support (Unspecified)**	**7**	**41.2**	**11.1**
Shaping Knowledge	**4.1 Instruction on how to perform behaviour**	**12**	**70.6**	**9.8**
Natural consequences	**5.1 Information about health consequence**	**6**	**35.3**	**1.8**
Comparison of behaviour	**6.1 Demonstration of the behaviour**	**2**	**11.8**	**2**
	6.2 Social comparison	**1**	**5.9**	**8**
Repetition and substitution	**8.1 Behavioural practice/rehearsal**	**6**	**35.3**	**21**
Antecedents	**12.5 Adding objects to the environment**	**3**	**17.6**	**1**

BCT, behaviour change technique

Number of BCTs and effect size

Subgroup analysis of which BCTs were associated with changes in physical activity outcome measures was not possible due to the small number of interventions included in the meta-analyses. The relationship between the total number of BCTs coded within an intervention and its effect size was found to be non-significant for MET ($r = 0.26$, $p = 0.65$) and for steps per day ($r = 0.89$, $p = 0.31$). Pearson's r correlation coefficient was not calculated for VO_2 Max or for the other six studies not included in the meta-analyses due to insufficient data.

6.5 Discussion

The aim of this review was to identify and summarise the effectiveness of physical activity interventions for pregnant women with overweight and obesity on physical activity levels. Furthermore, it set out to identify which BCTs are most frequently used in these physical activity interventions. Following a systematic screening process, 17 physical activity intervention studies were included. Due to the variation of physical activity outcomes, only 11 studies were included in the meta-analyses. Three small separate meta-analyses found a positive effect on MET minutes per week and VO_2 max for improving physical activity during pregnancy. As described by Currie et al 2013, physical activity tends to decrease gradually throughout pregnancy, therefore any outcome that demonstrates greater physical activity than control is deemed to be a desirable outcome (Currie et al., 2013). Thus, the results of this review suggest that physical activity interventions are to some extent useful for increasing physical activity levels for women with overweight and obesity. However, these results should be viewed with caution as the pool data came from studies that were highly heterogeneous. Despite physical activity reducing as pregnancy progresses due to the physical impediments experienced by women in the third trimester (Poudevigne & O'Connor, 2006), some of the studies in this review established some positive physical activity results including an increase in physical fitness and a slight reduction in the incidence of GDM (Koivusalo et al., 2016; Ong et al., 2009; Seneviratne et al., 2016). Nevertheless, these results should also be approached as tentative due to small number of studies and a lack of available data.

Eleven studies included in the three small separate meta-analyses found a main effect on physical activity outcomes for MET minutes per week and VO_2 max but not for steps per day which suggests that some physical activity interventions could be a beneficial strategy for improving physical activity during pregnancy. Additionally, five other studies (not included in the meta-analysis) reported an increase in physical activity or physical fitness for women in the intervention group compared to control. As physical activity guidelines recommend participation in moderate intensity activity on ‘most days’ (RCOG, 2006b), this is a positive finding regarding the efficacy of these physical activity interventions. However, the low number of studies and the inclusion of three pilot trials suggest that caution should be applied when interpreting these results. The wide range of physical activity measures used within the interventions reviewed creates difficulty for researchers and health care professionals trying to draw conclusions. For interventions that include a self-report measure of physical activity, social desirability bias may have led to women over reporting their physical activity levels. Although the majority of self-report questionnaires were based on valid and reliable measures, objective measures such as accelerometers have demonstrated a higher degree of reproducibility and validity for quantifying duration and intensity of physical activity (Bell et al., 2013; Corder, Brage, & Ekelund, 2007).

In the current study, the most commonly used BCT categories within the interventions were ‘goals and planning’, ‘feedback and monitoring’, ‘shaping knowledge’, ‘comparison of behaviour’, repetition and substitution’ and ‘antecedents’. Other studies that have used the BCTs taxonomy to code lifestyle interventions in pregnancy have also found that categories such as ‘goals and planning’ and ‘feedback and monitoring’ were the most frequently used (Gardner et al., 2011; Hill et al., 2013; Soltani, Arden, Duxbury, & Fair, 2016). In this review, ‘self-monitoring of behaviour’ (using items such as diaries or workbooks to monitor physical activity) and ‘instruction of on to perform the behaviour’ (providing participants with descriptions for particular exercises) emerged as the most frequently used BCTs across the interventions. The high implementation of these BCTs could possibly have contributed to the overall positive effects on physical activity. Research involving adults with overweight and obesity, also identified ‘self-monitoring of behaviour’ as a common BCT in physical activity interventions (Samdal, Eide, Barth, Williams, & Meland, 2017). Furthermore, a review examining the use of pedometers to increase physical activity, found significant increases in physical activity in an adult population (Bravata et al., 2007). In pregnancy, women with overweight and obesity have indicated that pedometers and step counts could help with self-monitoring (Flannery et al., 2018) with pedometers being found as an acceptable form of self-monitoring (Renault et al., 2010). Therefore, based on the results from this review and pervious research, future interventions should include some component of self-monitoring in order to improve physical activity levels for pregnant women with overweight and obesity. While the BCTs used to promote physical activity in this study correspond closely to those found in previous antenatal interventions (Gardner et al., 2011; Hill et al., 2013), the identification of 'social support' is unique to this population. Previous research has identified 'social influences' as an enabler to physical activity for women with overweight and obesity (Flannery et al., 2018), Furthermore, another study which investigated women's experiences of pregnancy found that physically active women faced some criticism from family members about their active lifestyles (Atkinson, Shaw, & French, 2016). Thus, future interventions need to take into account the woman's social support network, to include family, friends and other pregnant women in these antenatal interventions. As previously found, this result highlights the importance of selecting appropriate BCTs for each population and not assuming all BCTs will be equally effective.

Strengths and limitations

This systematic review was comprehensive in its scope and search and was conducted in accordance with the PRISMA (preferred reporting items for systematic reviews and meta-analysis) statement (Moher et al., 2009). A strength of this study was the use of an established instrument (BCTTv1) to systematically code the presence of BCTs in physical activity interventions for pregnant women with overweight and obesity.

Results from this review can be considered exploratory as the link between BCTs and intervention effectiveness were not explored and the presence of a BCT can only assume an association. This was due to the paucity of intervention studies. A higher number of RCT studies of physical activity interventions for women with overweight and obesity during pregnancy are needed to draw firm conclusions. The main limitations of this review stem from the inadequate reporting of physical activity data and poor intervention designs. Large differences in the type of activity measured, along with self-report measures highlights a limitation of the literature to date, making comparisons challenging. It is possible that higher sample sizes in the trial reported by Dodd et al (2014) and Poston et al (2013) may have diluted the overall meta-analysis for MET minutes per week due to greater weighing. Also the use of physical fitness as a secondary outcome measure can be difficult to interpret. The studies lacked sufficient data to calculate pooled effect sizes for all physical activity outcome measures. Unpublished studies were not included in the review so publication bias is not fully accounted for. Furthermore, even though publication bias was not detected or performed for all outcomes, the majority of studies were of poor quality. Due to the small number of studies included in the meta-analysis and the high degree of heterogeneity, caution must be applied when generalising these findings. The evidence base is weak and calls for more robust studies. Future research using robust high quality studies will foster better data to inform policy and practice.

The majority of interventions were based in a clinical setting which may have impacted intervention effectiveness. Furthermore, physical activity data were assessed using the last measure before birth (between 28-35 weeks gestation) thus reducing comparability between studies with follow up ranging from 8 weeks gestation to 12 month postpartum. Also, there were differences in the delivery modes and person, the intensity of the interventions and how active the women were prior to the intervention which may have also played a role in intervention effectiveness (and the BCTs used). As pregnancy progress women are more likely become less active (Gaston & Cramp, 2011), thus, future research is required to assess trimester (stage of pregnancy) and whether this impacts intervention effectiveness and the BCT employed.

Many studies failed to provide adequate information within the interventions in order to code for BCTs. As described by others, studies do not always provide adequate intervention content (Riley et al., 2008). Not all studies had associated methods or protocol papers available making it possible that other BCTs were used but not coded. This, however, is a common problem conducting reviews such as these (Dombrowski et al., 2012; Fredrix et al., 2018; Michie et al., 2009). Furthermore, correlation of BCTs and outcomes has previously been identified as a methodological weakness (Peters, de Bruin, & Crutzen, 2015). Although BCTs were easily identified in one control group, it is difficult to know if routine antenatal care provided a BCT or not. In order to reliably identify the BCTs associated with physical activity for women with overweight and obesity, control groups identified as routine care should be described in intervention reports and coded for BCTs. Furthermore, as one control group contained BCTs, this creates a potential source of bias affecting the reliability of the data. Fidelity was poorly reported so it was impossible to determine if BCTs were delivered or received as intended.

Some of the BCTs definitions were difficult to interpret, in particular ‘Information about health consequence’. This definition was not explicit about whether ‘health consequences’ related to the positive or negative health outcomes of performing or not preforming the behaviour, respectively. Therefore, after detailed discussion ‘Information about health consequence’ was coded for both. Issues also arose around the definition of ‘action planning’ and ‘behavioural practice and repetition’ and were settled after discussions. Furthermore, intervention components such as free gym membership and swimming pool vouchers were used within two intervention studies (Koivusalo et al., 2016; Vinter et al., 2011) and were not coded as BCTs; however these components could have an impact on behaviour change. In addition, contextual factors shape interventions and, therefore can influence how BCTs are delivered. Context can include individuals, teams, organisational structures and cultures, resources, leadership styles and relationships (McCormack et al., 2002; Wells, Williams, Treweek, Coyle, & Taylor, 2012).

Future intervention need to clearly define and report the behavioural outcome measure for physical activity and should follow TIdieR guidelines (Hoffmann et al., 2014). Moreover, interventions need to provide more transparent and comprehensive descriptions of BCTs used, BCTs in context, fidelity, dose and clarity regarding the theory used within the intervention. Improved intervention description including the use of recognised and standardised taxonomies would increase ability to assess the BCTs and to examine the relationship between technique usage and change in physical activity. Despite these limitations, it is important to conduct such reviews enabling researchers to describe and analyse in detail the content of interventions, aiding the accuracy and communication required to build a cumulative evidence base (Bishop, Fenge-Davies, Kirby, & Geraghty, 2015). Describing interventions in terms of BCTs, i.e. active ingredients, provides a useful level of detail for synthesis, comparison, and replication of interventions. The BCTTv1 provides a common language and definitions for understanding the content of interventions across contexts allowing the capacity to draw on insight from a range of populations to inform the design of future interventions (Michie et al., 2013).

6.6 Conclusion

The meta-analysis and narrative description of the included studies in this review revealed a slight increase in physical activity or physical fitness for pregnant women with overweight and obesity. A range of BCTs clusters that could be used to help improve physical activity levels during pregnancy were identified, including: ‘goals and planning’, ‘feedback and monitoring’ and ‘shaping knowledge’ with ‘social support’ being unique to this population. Given the importance of physical activity to many subsequent outcomes in pregnancy, an explicit theoretical basis is needed for intervention development. Furthermore, interventions need to not only report the presence and frequency of BCTs but also the intensity and quality in which they are delivered or implemented. As ‘social support’ was identified as unique to this population future interventions need to take into account woman’s social support networks, to include family and friends. These conclusions are tentative because of the poor methodological quality of the included studies. Therefore, future studies should consider physical activity measures carefully so that studies can be meaningfully compared and intervention developers need to use recognised and standardised taxonomies so that BCTs can be accurately assessed.

7 DISCUSSION

7.1 Discussion overview

This chapter will present a summary of the overall findings of this research and outline the contribution made by this research to the understanding of physical activity behaviour for pregnant women with overweight and obesity. The findings will be discussed in relation to the existing literature, followed by a discussion of the strengths and limitations of this research. Implications for research and practice will be highlighted to inform future research and intervention development. The final section of this chapter will contain overall concluding remarks.

7.2 Summary of research findings

The overarching aim of this thesis was to enhance our understanding of physical activity for pregnant women with overweight and obesity with the view to inform the development of a theoretically based behaviour change intervention to improve physical activity for these women. There are many interventions aimed at promoting lifestyle changes throughout pregnancy (Williams & French, 2011); however, these lifestyle interventions are often varied and report inconclusive results. Furthermore, these interventions often fail to consider the behaviour change techniques or relevant theories underlying the interventions. By following the MRC framework for intervention development, this research has advanced our understanding of physical activity for this high-risk pregnant population in a number of ways, which are outlined below.

The cross-sectional analysis using data from the SCOPE study provides an understanding of the social, biological, behavioural and psychological factors associated with physical activity in a healthy pregnant women population. The findings highlighted some key potential links with physical activity including a number of un-modifiable demographic correlates such as those of a young maternal age, those with a low education level and those from a low socioeconomic background. Pregnant women who consumed the recommended servings of fruit and veg per day and oily fish per week were more likely to be in the high physical activity subgroup. With women already engaging in healthy dietary behaviours, this could explain a potential spill over to physical activity. No behaviour sits in a vacuum, and one healthy behaviour can greatly affect another (Dolan & Galizzi, 2015). As diet and physical activity sit in the same behavioural cluster, future intervention efforts should look at behavioural clusters to improve physical activity levels during pregnancy.

The qualitative study identified the enablers and barriers to physical activity in pregnant women with overweight and obesity. Twenty one themes were identified and mapped directly on to the COM-B model of behaviour change and onto ten of the TDF domains. Having the social opportunity to engage in physical activity was identified as an enabler; pregnant women suggested being active was easier when supported by their partners. Knowledge was a commonly reported barrier with women lacking information on safe activities during pregnancy and describing the information received from their midwife as 'limited'. Having the physical capability and physical opportunity to carry out physical activity were also identified as barriers; experiencing pain, a lack of time, having other children, and working, prevented women from being active. In contrast to the SCOPE analysis, this study identified a number of modifiable factors such as more information on physical activity and time, which could enable physical activity during pregnancy.

Qualitative interviews with health care professionals, who provide care for pregnant women with overweight and obesity, revealed the challenges health care professionals face when trying to balance the medical and psychosocial needs of these pregnant women. Health care professionals discussed feeling uncomfortable and awkward when talking about weight and lifestyle with pregnant women. Their reluctance to engage in this discussion may explain why study 2 found that pregnant women received limited information regarding lifestyle factors, physical activity and weight from their midwives. Additionally, hospital based health care professionals such as obstetricians and midwives suggested that GPs were in a better position to deliver lifestyle and weight management advice.

Finally, the systematic review provides an evidence base around the content and effectiveness of existing physical activity interventions for pregnant women with overweight and obesity. The review found tentative evidence to suggest that physical activity interventions are to some extent effective at increasing physical activity levels for pregnant women with overweight and obesity. Across the included interventions, 'social support (unspecified)' was identified in this pregnant population, confirming results from the qualitative work with pregnant women identifying social influences as an enabler to physical activity. Furthermore, 'self-monitoring of behaviour' emerged as the most frequently implemented BCT which could possibly have contributed to the overall positive effects on physical activity. Despite efforts to identify relationships between BCTs and intervention effectiveness, the lack of physical activity data and the low number of included interventions limited the feasibility of these analyses. More research using objective physical activity measures and larger sample size is required to create more robust findings.

7.3 Contribution of this research

This programme of research advances understanding of physical activity during pregnancy in several ways. It provides an in-depth exploration of the barriers, enablers and determinants of physical activity for pregnant women with overweight and obesity, and the results provide important insights into this high risk population and a thorough foundation for intervention development. Furthermore, engagement with health care professional's revealed challenges faced within the antenatal service when caring for pregnant women with overweight and obesity. Following the MRC framework (intervention development framework) and utilising the TDF, COM-B model and BCTs (from behavioural science), the overarching results from this research indicated factors such as 'social support', 'goal setting' and 'self-monitoring of behaviour' as important behavioural components that may have a positive impact on improving physical activity in future interventions .

7.3.1 Social support

In the qualitative interviews pregnant women with overweight and obesity identified and discussed 'social support' as an important enabler to physical activity. This is consistent with reports of other qualitative studies identifying advice and support from women's social networks facilitating behaviour change during pregnancy (Evenson et al., 2009; Thornton et al., 2006). Similar to this research, previous research has indicated that health care professionals often give little or no informational support on physical activity or weight management in pregnancy (Clarke & Gross, 2004; Doran & O'Brien, 2007; Schmied et al., 2011; Smith et al., 2012). Interviews with health care professionals highlighted the challenges they face when trying to balance the medical and psychosocial needs of this high-risk population. Similarly, stigma surrounding obesity was present, which steered health care professionals approach to discussing lifestyle factors and weight management (Schmied et al., 2011). Furthermore, health care professionals discussed feeling uncomfortable and awkward when talking about weight with pregnant women, in particular, younger midwives, who lacked confidence and experience. This lack of confidence is supported by existing literature, with junior health care professionals having negative opinions about their skills for treating obese patients (Block et al., 2003; Brown & Thompson, 2007).

Health care professionals are ideally placed within the antenatal care setting, providing many clear opportunities to provide support (Schmied et al., 2011; van der Pligt et al., 2011). In Ireland, women experience frequent contact with a mix of health care professionals including obstetricians, GPs and midwives within the antenatal services. Therefore, educating and training health care professionals about physical activity and weight management during pregnancy would allow them to effectively provide consistent emotional and informational support throughout (Lawrence et al., 2016).

Similarly, the systematic review identified the BCT 'social support (unspecified)' within existing physical activity interventions for pregnant women with overweight and obesity. While the BCTs used to promote physical activity in this review corresponded closely to those found in previous antenatal interventions (Gardner et al., 2011; Hill et al., 2013) 'social support (unspecified)' was unique to the pregnant women with overweight and obesity. 'Social support (unspecified)' was not always defined or described within the included interventions, which in turn invites questions such as 'who provides this support, how do they provide it and when do they provide it?'. Social support has been defined as *"an exchange of resources between at least two individuals perceived by the provider or the recipient to be intended to enhance the wellbeing of the recipient"* (Shumaker & Brownell, 1984). Social support or social influence can occur when an individual's opinions, emotions and behaviours are affected by others (Shumaker & Brownell, 1984). Knowledge and skills can be acquired through social modelling (Bandura, 1986 - social cognitive theory), where individuals follow advice from people they trust (Bandura, 2004; Kwasnicka, Dombrowski, White, & Sniehotta, 2016). In previous studies, pregnant women have identified support from partners, family members and friends having a positive impact on health behaviours such as physical activity (Choi & Fukuoka, 2018; Heslehurst et al., 2015; Sui, Turnbull, & Dodd, 2013). Furthermore, spousal physical activity support was a predictor of other partners physical activity levels in non-pregnant populations, including middle-aged and older adults (Cobb et al., 2015; Satariano, Haight, & Tager, 2002).

Despite these positive impacts on physical activity, social support may not always have a positive effect on behaviour change. A study which investigated women’s experiences of pregnancy found that physically active women faced some criticism from family members about their active lifestyles (Atkinson et al., 2016). Furthermore, opinions of others formed or shaped pregnant women’s behaviours with some women conforming to social expectation and restricting their physical activity and others ignoring these concerns (van Mulken, McAllister, & Lowe, 2016).

Future research needs to investigate how support is supposed to work, how it works, and what its effects are on this target population (Kwasnicka et al., 2016). Traditionally, interventions primarily target the pregnant woman. However, the findings from this program of research indicate that antenatal interventions may need to go further, to include women’s social support networks such as partners and families within family-oriented behaviour change interventions. Interventions need to tap into women’s existing social networks, as these networks can be a facilitator to behaviour change. Providing women’s social support networks with knowledge of physical activity guidelines and awareness of the benefits of physical activity would ensure that women are adequately and positively supported throughout pregnancy.

7.3.2 Goal setting and self-monitoring

Through the qualitative interviews, pregnant women with overweight and obesity in this research identified ‘goal setting’ as an enabler to physical activity, with pedometers as a method of ‘self-monitoring’. While the pregnant women identified pedometers or step counts as important forms of self-monitoring, other forms of technology not have the same perceived benefit. Inconsistent with previous research, women disliked the idea of tracking physical activity in a phone apps (Kim et al., 2012; Kim, Niederdeppe, Graham, Olson, & Gay, 2015; O'Brien et al., 2014).

The concept of ‘goal-setting’ and ‘self-monitoring’ of behaviour plays a prominent role in many behaviour change interventions (Currie et al., 2013; Fredrix et al., 2018; Kwasnicka et al., 2016; Olander et al., 2013). Typically for obesity, interventions have targeted changes in diet and physical activity, using goal-setting, enhancing motivation, changing beliefs and providing self-regulation skills such as self-monitoring (Bandura, 2005; Sniehotta, Scholz, & Schwarzer, 2005). A wide variety of theories have been used to provide a theoretical organisation of these factors, including, social cognitive theories such as the theory of planned behaviour (Ajzen, 1991), theories of motivation such as self-determination theory (Deci & Ryan, 1985) and self-regulation models such as control theory (Michie, West, Campbell, Brown, & Gainforth, 2014b).

Self-monitoring of behaviour has been described as one of the most effective BCTs to support weight loss and increase physical activity (Dombrowski et al., 2012; Michie et al., 2009) and could be important for not only initiating behaviour but also for facilitating maintenance of behaviour change (Dombrowski et al., 2012). A previous study found that pregnant women who self-monitored their physical activity goals were more likely to be physically active into the later stages of pregnancy (Kim et al., 2015). Furthermore, the findings also suggested that repeated self-monitoring can help maintain pregnant women's positive intentions, enabling them to strive for more long-term physical activity goals (Kim et al., 2015).

The systematic review identified 'self-monitoring of behaviour' (using diaries, workbooks or pedometers to monitor physical activity). 'Self-monitoring of behaviour' emerged as the most frequently used BCTs across the existing physical activity interventions included in the review. The high implementation of self-monitoring in these interventions could have contributed to the overall positive effects on physical activity. Research involving adults with overweight and obesity also identified 'self-monitoring of behaviour' as a common BCT in physical activity interventions (Samdal et al., 2017). Furthermore, previous research with pregnant women with overweight and obesity indicated that pedometers and step counts are an acceptable form of self-monitoring (Flannery et al., 2018; Renault et al., 2010). People need feedback on their performance levels to adjust the level or direction of their set goal; they also need a suitable from of self-monitoring. Thus, future interventions should include 'goal-setting' and some component of 'self-monitoring of behaviour' to improve physical activity levels for pregnant women with overweight and obesity.

7.3.3 The use of behavioural frameworks and taxonomies

The use of behavioural frameworks and taxonomies from behavioural science plays a prominent role in this research. The use of the TDF and the refinement of the theoretical domains into the COM-B model clarified which barriers and enablers should be targeted to improve physical activity participation for pregnant women with overweight and obesity. The large pool of theoretical models available means that it can be challenging to select the most appropriate theory for the behaviour in question (Michie et al., 2011a; Michie et al., 2011c). Using these frameworks, overcomes this difficulty, as they are derived from many theories and psychological constructs (Michie et al., 2011c). The COM-B provides a framework that can be applied to behaviour in any setting. However, while the TDF and COM-B model did offer a comprehensive framework within this PhD research, at times, it was difficult to categorise themes due to the lack of clarity in the definitions. This problem has been previously identified when trying to clarify the boundaries between some domains (Little, Presseau, & Eccles, 2015). Therefore, some refinements may need to be made to the domain definitions.

The BCT taxonomy was developed to provide a precise and systematic method of describing the active content of interventions (Michie et al., 2013). This, in turn, has allowed for intervention content to be retrospectively coded using these agreed labels and definitions (Fredrix et al., 2018; Gardner, Smith, Lorencatto, Hamer, & Biddle, 2016). However, a recent scoping review revealed that studies retrospectively coded using the taxonomy report a lack of confidence in their findings due to limitations such as research heterogeneity, a lack of published studies, a lack of clear intervention descriptions, and limited fidelity of delivery assessment in published studies (Michie, West, Sheals, & Godinho, 2018). Consistent with these findings, the systematic review in this research also faced these challenges.

Although the BCT taxonomy is an internationally recognised categorisation tool, most interventions included in the review failed to provide adequate information to code for BCTs. As described by others, studies do not always provide sufficient intervention content (Riley et al., 2008). Furthermore coding BCTs requires the coder to code if the BCT is ‘absent’, ‘probably present’ and ‘definitely present’. This method does not account for the ‘dose’ of a BCT, how frequently or intensely the BCT is presented making it impossible to determine if BCTs were delivered or received as intended. Health psychologists are trying to improve reporting of intervention content (Knittle, 2015) which in turn, should make synthesising behaviour change evidence easier (Presseau et al., 2015). Nevertheless, by exploring the BCTs in existing physical activity interventions, this research has created a better understanding of the current application of these theoretical constructs.

7.3.4 Theory and physical activity

The theoretical approaches to physical activity are abundant and only a few were discussed in the introductory chapter of this PhD thesis (Chapter 1, section 1.6). Theoretically-informed interventions are claimed to be superior as they identify key mediator mechanisms of change (Baranowski, Lin, Wetter, Resnicow, & Hearn, 1997). However, previous reviews and the systematic review in this PhD thesis show that theory was not always used in the design of such interventions (Prestwich et al., 2014). A meta-analysis showed that the effect of theory-based interventions on physical activity behaviour was small (effect size d= .31), and that single-theory interventions produced slightly stronger effect sizes than multiple theory interventions (d=.35 vs d=.21) (Gourlan et al., 2016). This raises a number of questions about theory based interventions, the value in using theory based approaches to improving physical activity and how these theory based interventions are designed, implemented and evaluated. According to Ekkekakis (2017), future research should focus on the affective experience of physical activity and move beyond information-processing models that emphasise cognitive processes as determinants of exercise. Furthermore, Ekkekakis (2017) calls for researchers to invest time and effort into investigations designed to develop and test methods of making the experience of physical activity more pleasant for individuals across all stages of life (Ekkekakis, 2017).

7.4 Implications for policy

In the qualitative work with health care professionals they discussed how obesity is being normalised in society and how the perception of obesity is changing rapidly for the general public and health care professionals, with implications for the health and well-being of pregnant women with overweight and obesity. Irish healthcare policy recognises the issue of obesity and pregnancy in recent policy documents including the 'Healthy Ireland' obesity policy and action plan, and the National physical activity plan for Ireland (Executive, 2013; Healthy Ireland, 2013). Furthermore, the Health Service Executive (HSE) published a 'Reference Guide for Primary Care' and 'Clinical Practice

Guidelines', both of which set out recommended levels of physical activity (Health Service Executive, 2013; HSE/ICGP, 2013). The 'Clinical Practice Guidelines' called 'Obesity and Pregnancy' provides guidelines on physical activity, diet, caesarean section, hypertension and gestational diabetes. Findings from this programme of work could potentially improve the usefulness of these documents as it provides contextual information on the barriers, enablers and determinants of physical activity from the perspective of pregnant women with overweight and obesity (Appendix B, Figure 12 Research Brief). Furthermore, this research highlights the challenges that health care professionals face when addressing lifestyle factors and weight management for this high-risk group. Health promotion campaigns highlighting physical activity recommendations and benefits of physical activity in pregnancy are needed. Also, findings from this research could inform the development of local guidelines to ensure that health care professionals provide more consistent weighing practices and weight management. Unbiased syntheses of existing information and research on behaviour change are two of the most important contributions researchers can offer to policymakers (Whitty, 2015), both of which are presented in this PhD research. These findings can be used to inform the development of an antenatal lifestyle intervention; to determine the most appropriate intervention functions, effective BCTs and implementation plan most likely to affect physical activity behaviour pregnant women with overweight and obesity.

7.5 Implications for practice

Pregnancy has been identified as a "teachable moment" where woman's health motivations could be harnessed for long-term behaviour change and wider public health benefits beyond pregnancy, given women's vital role in supporting healthy lifestyles in the wider family unit (Phelan, 2010). Pregnancy presents an opportunity, as women are engaged with their health care professionals and GPs and when behaviours are possibly more modifiable (Phelan, 2010). The qualitative work indicated that not only do pregnant women with overweight and obesity women require more intensive education and advice but health care professionals also need some level of training and skill development to provide lifestyle advice and weight management as part of routine antenatal care. Consistent with previous research, lack of confidence to discuss weight and concerns about the perceived negative impacts of discussing weight with pregnant women was identified in the interviews with health care professionals (van der Pligt et al., 2011; Wilkinson & Stapleton, 2012; Willcox et al., 2012). Health care professions need to learn from other areas of public health such as smoking, where smoking cessation services, training and supports are in place (Blackburn, Stathi, Keogh, & Eccleston, 2015).

Despite international guidelines for weight management in pregnancy (Institute of Medicine, 2009), the health care professionals interviewed were not following or adhering to these recommendations. Echoed in previous research, weighing practices were not viewed as an important clinical indicator, despite the subsequent co-morbidities associated with overweight and obesity in pregnancy (Johnson et al., 2013; Renault et al., 2014). GPs, obstetricians and midwives need to set aside more time for weighing their pregnant women patients, providing antenatal counselling on weight management and adhering to international weight management guidelines.

7.6 Future research

This PhD research identified areas that require further investigation. Given the use of cross-sectional data in the description of physical activity levels during pregnancy, the results do not account for exercise conditions throughout pregnancy or the variation in exercise that may occur from trimester to trimester. Therefore, future longitudinal follow up studies are warranted to measure physical activity throughout pregnancy. While a broad representation of pregnant women with overweight and obesity across various socio-economic status and cultural backgrounds were recruited for interviews, future research is warranted to assess non-caucasian, racial or cultural differences in pregnant women with overweight and obesity. Future interventions need to use more objective approaches to measuring physical activity so that intervention results can be pooled for systematic reviews of these interventions. Furthermore, although the BCT taxonomy was useful to provide a precise and systematic method of describing the active content of interventions (Michie et al., 2013), it does not capture fidelity or dosage (Peters et al., 2015). Future studies need to improve the reporting of interventions (Knittle, 2015), to make it easier to synthesise behaviour change evidence.

Next steps for intervention development

This PhD thesis highlights the importance of research with key stakeholders in order to design and develop an intervention. As this research uses the BCW within the overarching MRC framework, the eight steps of the BCW are mapped onto the three stages of the MRC framework. The next steps within the BCW that need to be addressed are presented in Table 12.

Table 12: Next steps for intervention development using the behaviour change wheel

MRC Framework	BCW Stages	BCW steps completed in this PhD Research	BCW steps to be addressed
1. Identify the evidence base	1. Understand the behaviour	1) Defined the problem 2) Selected the target behaviour (PA) **(Study 1-4)**	3) **Specify the target behaviour** Involves specifying the behaviour in detail and in context by answering: What is the behaviour that will be targeted for change? Who performs the behaviour? When and where do they perform the behaviour?
2. Identify/develop theory	2. Identify intervention options	4) Identified what needed to change using the TDF and COM-B model **(Study 2)**	5) **Identify appropriate intervention functions** Involves identifying interventions functions likely to be effective in bringing about change 6) **Identify policy categories** Involves identifying which policies would support the delivery of the intervention functions
3. Model process and outcome	3. Identify content and implementation options	7) Identified behaviour change techniques used within existing PA interventions **(Study 4)**	8) **Determine mode of delivery** Involves identifying possible modes of delivering the intervention

BCW, behaviour change wheel; TDF, theoretical domains framework; BCT, behaviour change technique; PA, physical activity

In line with the MRC Framework for Intervention Development and the Behaviour Change Wheel, future research is needed to complete the final steps listed in Table 12 in order to develop a physical activity intervention. The Behaviour Change Wheel and related models will be explicitly used to integrate behavioural theory with data from studies 1-4 in this PhD. This will help to specify the target behaviour, identify theory and model processes and outcomes. The COM-B model used in study 2 will guide the choice of intervention strategies most likely to achieve behaviour change, while the BCT coding in study 4 identifies the techniques most frequently used to deliver physical activity interventions to pregnant women with overweight and obesity. The combination of intervention strategies, policy categories, and techniques will be integrated and developed into a complex behaviour change intervention. This work would then be followed by a pilot trial to test the feasibility of the intervention (Medical Reseach Council, 2008). A feasibility trial would allow the processes of carrying out a larger trial to be tested and make final refinements before effectiveness is tested in a fully powered RCT.

The range of methodological and theoretical approaches used here warrant greater consideration by other researchers interested in intervention development. This research has shown that the Behaviour Change Wheel is useful for operationalising the guidance of the MRC framework and providing a systematic approach to intervention development. Recently, researchers have acknowledged some challenges associated with the Behaviour Change Wheel and have highlighted that '*it is not the magic bullet for intervention development'* (Ogden, 2016; Sinnott et al., 2015). As experience with these models grows, other pragmatic approaches to intervention development may develop (Hoddinott, 2015).

Interventions need to provide the participants with adequate information regarding the benefits of being physically active, the recommended guidelines, and instructions on how to perform the behaviour. Furthermore, some form of 'self-monitoring' such as pedometers should be included so that women can set goals and monitor their progress. Interventions should also try to involve the women's 'social support' networks to include family and friends within the intervention. Finally, if health care professionals are to deliver interventions such as this, they themselves will need education and training to ensure consistent information is provided through antenatal care.

7.7 Strengths and limitations

This section provides a synopsis of the overall strengths and limitations of this thesis. The strengths and limitations of the individual papers have been acknowledged and addressed within the study chapters.

One of the major strengths of this PhD research was the iterative development of the studies through the use of the Medical Research Council Framework (MRC) 'Development' phase 1. The MRC framework states the need to identify the evidence base and supplement with new evidence if necessary. In doing this, this programme of research provides much needed data on physical activity for pregnant women with overweight and obesity. Using a developmental research approach such as this for intervention development allows the best chance of the subsequent interventions being effective in a real-world setting and being engaging and useful to participants (Bowen et al., 2009; Collins et al., 2005; Collins, Murphy, & Strecher, 2007).

The concurrent mixed methods research design allowed for flexibility in the research process so that each piece of work could be conducted. The use of a range of research methodologies to explore different aspects of physical activity, including a cross-sectional analysis of the SCOPE data, qualitative research with pregnant women and health care professionals, and a systematic review of the existing evidence was a strength of this PhD research. In this research health care professionals and pregnant women were recruited and interviewed from the same antenatal clinic, thereby, providing both perspectives from within the same context. A further strength of this thesis is that it addresses a topical and timely research area in Irish policy.

There is a debate on the value of theory in intervention development (Prestwich et al., 2015). However, within this programme of research the theoretically informed approach using the MRC framework, the TDF and COM-B model was useful. It lent clarity and structure to the process of intervention development. The use of the Behaviour Change Wheel allowed for a systematic, evidence base and theory-driven process to follow to identify the unique needs of this target group. The final strength of this PhD is that it provides practical recommendations and a thorough grounding for intervention development, to identify the target behaviour, select intervention functions and to develop a theory based intervention strategy.

As with all research, there are also limitations in this work**.** The multiple steps involved in intervention development have been noted previously by other researchers as 'time-consuming' (Murtagh, Barnes, McMullen, & Morgan, 2018; Sinnott et al., 2015). While this work was essential to inform intervention development, its lengthy process meant that developing a tangible intervention programme was beyond the scope of this PhD thesis. Future funding will be sought to continue this work.

7.8 Conclusion

This PhD research advances our understanding of physical activity for pregnant women with overweight and obesity. The results indicate that future interventions need to provide women with adequate information regarding the benefits of physical activity, the recommended guidelines, and instructions on how to perform the behaviour. Furthermore, some form of 'self-monitoring' such as pedometers should be included so that women can set goals and monitor their progress. Interventions should also try to involve the women's 'social support' networks to include family and friends within the intervention. Using behavioural science, the findings from this PhD research provide a 'stepping stone' for intervention development to improve physical activity for pregnant women with overweight and obesity.

8 APPENDIX A: SUPPLEMENTARY MATERIAL STUDY 1

SCOPE Research Application Form

APPLICATION FORM
SCOPE RESEARCH PROJECT

RAF Number: 3.66
Project Title: Modifiable factors associated with Physical Activity during pregnancy
Project PI: Patricia Kearney
Other Researcher(s): Caragh Flannery, Sheena Mc Hugh, Molly Byrne
Date of Submission: 07/11/2017
Mark X in each centre involved in the research

	SCOPE Centres involved in research	SCOPE Biobanks Data involved in research	SCOPE Biobanks Specimen use in research
Auckland			
Adelaide			
Manchester			
Kings			
Leeds			
Cork	x		

Funding required to do project **no** **(delete as appropriate)**

Funding Status	Yes	No	N.A.	Funder/Amount funded/Date
Applied for funding		x		
Planning to apply for funding		x		
Funder/Potential Funder				
Date expect to hear outcome of funding application				
Date heard outcome of application				
Funded				
Amount funded				

Ethics
Ethical Approval is required for all SCOPE clinical centres, and women consent prior to participating. Most projects should be covered by this consent, but there may be occasion when additional ethical approval is required.
Ethics Approval complete ~~yes~~ /no
Collaboration with Commercial Institution or Academic Inst. outside SCOPE Consortium **NO**

If yes, please complete this table:

Commercial Details	Complete details
Name of Company/ Academic Institution	
Type of Collaboration	
IP ownership solved	
If IP ownership solved, please summarise solution	
If IP ownership not solved, summarise issues	

Research Proposal

Introduction

In this era of obesity, excessive gestational weight gain and obesity during pregnancy are increasing public health concerns. Obesity during pregnancy is associated with a number of adverse maternal and neonatal outcomes including risk of gestational diabetes, pre-eclampsia, caesarean section, instrumental delivery and preterm delivery (1). Current national and international guidelines (ACOG and RCOG) recommend 30 minutes of daily moderate intensity physical activity (PA) for pregnant women (2, 3). Despite these recommendations, many pregnant women reduce their activity levels in pregnancy and in Ireland, a recent study reported that only one-fifth of pregnant women met the guidelines and over 10% reported no physical activity (4). In Norway a survey showed that only 14.6% of women followed recommended guidelines for PA (5). Factors like BMI, unemployment and educational levels have been shown to influence physical activity levels (5, 6). Pregnancy has been identified as a unique screening and intervention opportunity for obese women as it is said to be a 'teachable moment' that can create positive outcomes for mother, baby and society (7). Pregnancy may also provide an opportunity for behavioural change in particular if these lifestyle changes impact on the health of the foetus. Several reviews have highlighted numerous gaps and inconsistencies in the evidence base regarding physical activity levels in pregnancy. Some trials that included PA demonstrated positive effects. For example, in the TOP (Treatment of Obese Pregnant women) study of 425 obese pregnant women in Denmark, gestational weight gain was lower in women randomised to receive a physical activity intervention (8). In the LIMIT RCT of a combined diet and physical activity lifestyle advice intervention in 2212 overweight and obese pregnant Australian women, fewer macrocosmic infants were born to women randomised to receive lifestyle advice (9). These findings reinforce the importance of identifying ways of supporting pregnant women to make healthy lifestyle choices in terms of PA.

In order to examine PA levels, we aim to examine the impact of other health behaviours (diet, vitamin and minerals, drugs, alcohol and sleep) and psychological well-being (perceived stress scale, behavioural responses to pregnancy, state trait anxiety inventory, depression scale, postnatal depression score) on physical activity levels using the bio-psychosocial model. More specifically using the Irish cohort of the SCOPE data this study aims to:

1. To estimate the levels of PA during pregnancy, in particular PA levels among women in different BMI categories.
2. To identify modifiable behavioural and psychosocial factors that influence PA during pregnancy.
3. To examine behavioural responses to pregnancy.

Methods:

Descriptive statistics will be used to describe physical activity levels among women in Cork. Physical activity levels will be looked at the different time points (15wks and 20wks gestation). T-tests will be used for continuous variables and chi-squared tests for categorical variables. Using the bio-psychosocial model (biological, psychological, Socio-demographic and behavioural), logistic regression analyses will be used to model the association between potential modifiable predictors and physical activity level over time (15wks and 20wks).

Design:

Prospective cohort of Cork women in SCOPE and their new-borns.

Other Comments: NONE

Planned commencement date: June 2015

Expected finish date: September 2015

Project Agreement required	no (delete as appropriate)
Project Agreement completed	no (delete as appropriate)

Table 13: SCOPE Questionnaire at 15 weeks

1st Lifestyle Questionnaire 15 weeks

Study ID ______________ Date ____________________ Initials ______________

Participant completed questionnaire: Yes, by self____ Yes, with MW____ No____

This questionnaire asks about how you spend your time, your work and exercise, how you manage your pregnancy, about your feelings and relationships.

In an average week, I spend (hours in total should not exceed 168h)

_____ Hours at paid employment
_____ Hours studying
_____ Hours of household duties
_____ Hours relaxing (reading, hobbies etc)
_____ Hours exercising

Work

If you do paid work, please complete the next questions. If not, turn the page.

How would you describe your activities at work?

Circle **the one that best describes your main activities at work**

1. Administrative/sitting activities
2. Sitting and some walking
3. Standing
4. Standing & walking
5. Standing & walking work plus intermittent strenuous exercise
6. Regular strenuous exercise

Revised 15 weeks lifestyle questionnaire Feb2007 SCOPE Confidential

1

This asks you about how you feel at the end of your normal working day. Please answer these questions in relation to how you have been feeling **in THE PAST MONTH by *ticking either* Yes *or* No.**

Yes	No	
☐	☐	I find it hard to relax at the end of a working day
☐	☐	At the end of a working day I am really feeling worn-out
☐	☐	My job causes me to feel rather exhausted at the end of a working day
☐	☐	I have trouble concentrating in the hours off after my working day
☐	☐	I find it hard to show interest in other people when I just came home from work
☐	☐	In general, it takes me over an hour to feel fully recovered after work
☐	☐	When I get home, people should leave me alone for some time
☐	☐	After a working day I am often too tired to start other activities
☐	☐	During the last part of the working day I cannot optimally perform my job because of fatigue sometimes
☐	☐	Generally speaking, I'm still feeling fresh after supper
☐	☐	Generally speaking, I'm able to relax only on a second day off

Cohen Perceived stress 10 scale. (range 0-30)

Stress

The next questions ask about your feelings and thoughts during THE LAST MONTH.

In each case, you will be asked to indicate how often you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is to answer each question fairly quickly. Don't try to count up the number of times you felt a particular way, but rather ***circle the answer that you think best fits for you***.

	Never	Almost Never	Some-times	Fairly Often	Very Often
In the last month, how often have you been upset because of something that happened unexpectedly?	0	1	2	3	4
In the last month, how often have you felt that you were unable to control the important things in your life?	0	1	2	3	4
In the last month, how often have you felt nervous and stressed?	0	1	2	3	4
In the last month, how often have you felt confident about your ability to handle your personal problems?	0	1	2	3	4
In the last month, how often have you felt that things were going your way?	0	1	2	3	4
In the last month, how often have you found that you could not cope with all the things you had to do?	0	1	2	3	4
In the last month, how often have you been able to control irritations in your life?	0	1	2	3	4
In the last month, how often have you felt that you were on top of things?	0	1	2	3	4
In the last month, how often have you been angered because of things that happened that were outside of your control?	0	1	2	3	4
In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	0	1	2	3	4

Exercise and Sleep Now

1. **On average, how many hours do you currently spend each day doing the following?** Please fill in the number of hours for each activity.

Standing (include standing still, walking, exercising or any other activity which involves being on your feet)	on weekdays	_____hours	on a weekend day	_____hours
Sleeping during the day	on weekdays	_____hours	on a weekend day	_____hours
Sleeping at night	on weekdays	_____hours	in the weekends	_____hours
		Must be <24 hrs in total		*Must be <24 hrs in total*

2. **Has your level of exercise (physical activity) changed since you've been pregnant? (*Circle* the answer)**

1 - Decreased	**2** - Unchanged	**3** - Increased

For the next questions, please *circle* which fit best with what you have done in the LAST MONTH (except questions 8 and 9 which relate to walking in the last week):

3. **In the last month, how many times do you usually wake during a night's sleep?**

1 - Don't usually wake up	**2** - Once a night	**3** - 2-3 times	**4** - 4 or more times

4. **Do you snore most nights?**

1 - No	**2** - Yes	**3** – Don't know

5. **How often have you engaged in vigorous exercise in the last month (exercise which made you breathe harder or puff or pant such as tennis, jogging, aerobics, heavy gardening, rollerblading, skiing, rowing, rowing/cycling machine)**

1 - Never	**2** - Once a week	**3** - 2-3 time each week
4 - 4-6 times each week	**5** - Daily	**6** - More than once a day

6. **How often have you engaged in less vigorous exercise for recreation, sport or health-fitness purposes in the last month which did not make you breathe harder or puff and pant?**

1 - Never	**2** - Once a week	**3** - 2-3 time each week
4 - 4-6 times each week	**5** - Daily	**6** - More than once a day

7. **How often have you walked for recreation or exercise in the last month?**

1 - Never	**2** - Once a week	**3** - 2-3 time each week

4 - 4-6 times each week	**5** - Daily	**6** - More than once a day

8. How many times in the <u>last WEEK</u> did you walk for a purpose rather than for fun (e.g. walking to bus stop or train to work or shopping)?

1 – never	**2** – once	**3** –twice
4 – 3-5 times	**5** – 6-10 times	**6 -** More than 10 times

9. If you walked for a purpose in the <u>last WEEK</u> (e.g. walking to bus stop or train to work or shopping), on average how many kilometres did you walk each time?

__________kilometres

10. How many times did you climb a flight of stairs in the <u>last month</u>? *(not just a few steps into the house)*

1 - Never	**2** - Less than 10 times per day	**3** - At least 10 times per day

11. In the <u>last month</u>, on average, how many hours did you spend watching television in a day?

1 - None	**2** - Less than 2 hours	**3** - 2-4 hours	**4** - 5-6 hours	**5** – more than 6 hours

12. In the <u>last month</u>, on average, how many hours did you spend using a computer in a day?

1 - None	**2** - Less than 2 hours	**3** - 2-4 hours	**4** - 5-6 hours	**5** – more than 6 hours

Behavioural Response to Pregnancy

Your Responses to Your Pregnancy?

6-24 with high score indicating high state anxiety

The statements below refer to things that you may or may not have done to manage your pregnancy.

How often you have done the following since you found out you were pregnant? Please ***circle the answer that you think best fits for you***

	Not at all	Rarely	Some days	Most days	Everyday
I have overdone things, then needed to rest up for a while	0	1	2	3	4
I have avoided physical exercise	0	1	2	3	4
I have put parts of my life on hold	0	1	2	3	4
I have not been able to carry on with my usual level of activity	0	1	2	3	4
I haven't slowed down, I've just carried on as normal	0	1	2	3	4
I have felt better than ever	0	1	2	3	4
I have pushed myself as hard as ever until I can not push myself any more	0	1	2	3	4
I have gone to bed during the day	0	1	2	3	4
I have carried on with things as normal until my body can not cope any longer	0	1	2	3	4
I have felt obliged to carry out all my responsibilities, no matter how bad I feel	0	1	2	3	4
I have avoided my usual activities	0	1	2	3	4
I have tried to do too much and felt even worse as a result	0	1	2	3	4
I find myself rushing to get everything done before I crash	0	1	2	3	4

Range (6-24)

How are you Feeling?

Please read each of the following statements and circle the most appropriate number to the right of the statement to indicate **how you feel right now**, at this moment. Do not spend too much time on any one statement but ***circle*** the answer which seems to describe your present feelings best.

6 item short-form of State-trait Anxiety Inventory.

	Not at all	Somewhat	Moderately	Very Much
I feel calm	0	1	2	3
I feel tense	0	1	2	3
I feel upset	0	1	2	3
I feel relaxed	0	1	2	3
I feel content	0	1	2	3
I feel worried	0	1	2	3

Mood

Edinburgh Postnatal Depression Scale.

The following questions ask about your mood.

Please ***circle*** the answer that best describes to how you have felt in **THE PAST WEEK.**

1. **I have been able to laugh and see the funny side of things:**

   1 - As much as I always could | **2** - Not quite so much now | **3** - Definitely not so much now | **4** - Not at all

2. **I have looked forward with enjoyment to things:**

   1 - As much as I ever did | **2** - Rather less than I used to | **3** - Definitely less than I used to | **4** - Hardly at all

3. **I have blamed myself unnecessarily when things went wrong:**

   1 - No not at all | **2** - Hardly ever | **3** - Yes, sometimes | **4** - Yes, very often

4. **I have felt anxious or worried for no very good reason:**

   1 - Yes, quite a lot | **2** - Yes, sometimes | **3** - No, not much | **4** - No, not at all

5. **I have felt scared or panicky for no very good reason:**

   1 - Yes, quite a lot | **2** - Yes, sometimes | **3** - No, not much | **4** - No, not at all

6. **Things have been getting on top of me:**

1 - Yes, most of the time I haven't been able to cope at all	**2** - Yes, sometimes I haven't been coping as well as usual
3 - No, Most of the time I have coped quite well	**4** - No, I have been coping as well as ever

7. **I have been so unhappy that I have had difficulty sleeping:**

1 - Yes, most of the time	**2** - Yes, sometimes	**3** - Not very often	**4** - No, not at all

8. **I have felt sad or miserable:**

1 - Yes, most of the time	**2** - Yes, quite often	**3** - Not very often	**4** - No, not at all

9. **I have been so unhappy that I have been crying:**

1 - Yes, most of the time	**2** - Yes, quite often	**3** - Only occasionally	**4** - No, never

10. **The thought of harming myself has occurred to me:**

1 - Yes, quite often	**2** - Sometimes	**3** - Hardly ever	**4** - Never

Relationships and Support

The last questions are about your Relationships and Support.

Please *circle* the answer that you think best fits for you

	All of the time	Most of the time	Some of the time	Seldom	Never
Do you have people around you who can help with practical things when you need it?	1	2	3	4	5
Do you have people around you who can help or listen to you when you feel down, upset or worried?	1	2	3	4	5
Do you have anyone around you who you are frightened or scared of?	1	2	3	4	5

If you have a partner, is he the father of your baby? Please *circle* which applies

1 - yes	**2** - no	**3** - unsure

We know that many women are hurt in their relationships and we are asking all women in the study a few questions about this. If you find the questions upsetting or if you need help/support, we have information about available support services.

Are you happy to answer questions about physical violence? YES ☐ NO ☐

If you are willing to answer, please complete below. If you feel unable to answer these questions, please leave the rest blank and return questionnaire to the midwife."

Please ask if you would like or need some support.

1. **During the _12 months before this pregnancy_ have you been hit, slapped, kicked or physically hurt by anyone? Please _circle_ all that apply.**

	Never	Once	2-5 times	More than 5 times
Husband or partner	0	1	2	3
Ex husband or partner	0	1	2	3
Family member other than your husband or partner	0	1	2	3
Friend or acquaintance	0	1	2	3
Stranger	0	1	2	3
Someone else	0	1	2	3

2. **During _this pregnancy_ have you been hit, slapped, kicked or physically hurt by anyone? Please _circle_ all that apply.**

	Never	Once	2-5 times	More than 5 times
Husband or partner	0	1	2	3
Ex husband or partner	0	1	2	3
Family member other than your husband or partner	0	1	2	3
Friend or acquaintance	0	1	2	3
Stranger	0	1	2	3
Someone else	0	1	2	3

3. **During the _12 months before this pregnancy_ were you ever physically forced to have sexual intercourse by anyone? Please circle all that apply.**

	Never	Once	2-5 times	More than 5 times
Husband or partner	0	1	2	3
Ex husband or partner	0	1	2	3
Family member other than your husband or partner	0	1	2	3
Friend or acquaintance	0	1	2	3
Stranger	0	1	2	3
Someone else	0	1	2	3

4. **During *this pregnancy* were you ever physically forced to have sexual intercourse by anyone? Please *circle* all that apply.**

	Never	Once	2-5 times	More than 5 times
Husband or partner	0	1	2	3
Ex husband or partner	0	1	2	3
Family member other than your husband or partner	0	1	2	3
Friend or acquaintance	0	1	2	3
Stranger	0	1	2	3
Someone else	0	1	2	3

5. **During *this pregnancy* have you had sexual intercourse because you were afraid of what any of these people might do to you? Please *circle* all that apply.**

	Never	Once	2-5 times	More than 5 times
Husband or partner	0	1	2	3
Ex husband or partner	0	1	2	3
Family member other than your husband or partner	0	1	2	3
Friend or acquaintance	0	1	2	3
Stranger	0	1	2	3
Someone else	0	1	2	3

If you have been hurt, then ***circle*** the one that applies:

6. **Compared to the *12 months before your pregnancy*, during this pregnancy have you been hurt**

1 - More often	**2** - Less often	**3** - Same	**4** – Not Applicable

Table 14: SCOPE variables – Codebook

Variable name	*Coding*	*Coding for PhD work*
PA		
Vigorous exercise ***(exercise which made you breathe harder or pant)*** **Moderate exercise** ***(exercise which did not make you breathe harder or pant)*** **Recreational walking** ***(walking for recreation or exercise)***	*Never;* *Once a week;* *2-3 times a week;* *4-6 times a week;* *daily;* *More than twice daily.*	***Used in the Latent class analysis***
PA		
PA subgroups	*Low* *Moderate* *High*	*Latent class analysis was used to identify mutually exclusive subgroups in the sample of participants based on these three categorical survey items*
Social measures		
Maternal age	*Years or age category;* *<25 year,* *25-29 years,* *30-34 years,* *≥35years*	
Ethnicity	*Asian* *Caucasian* *Other* *Maori* *African* *Indian* *Pacific Islander*	*Caucasian vs. non-Caucasian*
Relationship status	*Single* *Married* *Defacto (stable relationship, not married)* *Separated or Divorced* *Same sex partner*	*Single,* *married/partner*
Employment status	*Full time work* *Part time work* *Student* *Homemaker* *Unemployed* *Other*	*Working vs. not working*
Accommodation	*Own house* *Rental* *Other accommodation*	*Own home vs. other*

Table 14: SCOPE variables – Codebook (continued)

Variable name	Coding	Coding for PhD work
Education	*Continuous data for years of schooling*	*≤ 12 years of schooling vs. > 12 years of schooling*
Type of maternity care services		*Public vs. Private*
Socioeconomic index (SEI		*New Zealand SEI (<24 vs. ≥24)*
Biological measures		
Gravidity		(*1* vs. > *1*)
Pre-pregnancy body mass index		*Underweight <18.5kg/m^2, Normal weight 18.5 - 24.9kg/m^2, Overweight ≥25 – 29.9kg/m^2, Obese ≥30kg/m^2*
Psychological and behavioural measures		
Alcohol	*No drinks; 1-2 drinks; 3-7 drinks; 8-14 drinks; >14 drinks*	*Drinkers (≥ 1 drink) vs. non-drinkers (no drink))*
Smoking	*No smoking; 1-5 cigarettes; 6-10 cigarettes; >10 cigarettes*	*Categorised as (smokers (≥1 cigarettes) vs. non-smokers (no smoking)).*
Pre-pregnancy folic-acid supplementation *(no, yes),*		*Responses (dose) were dichotomized as those meeting the recommended 400 µg vs. those who did not (Yes vs. No).*
Consumed fruit & vegetables	*Recommended five servings of fruit and veg per day (Yes vs. No),*	
Fish	*At least 1 serving of oily fish per week (Yes vs. No).*	

Table 15: Psychological well-being and their interpretations

Psychological and behavioural scales	Score range and interpretation
Short form of the State Trait Anxiety Index (STAI)	Short –form STAI scores 6-24 converted to a score range of 20-80 to mimic the full version of the STAI, with high scores indicating high state anxiety (i.e. current anxiety)
Perceived Stress Scale (PSS)	0-40, with high scores representing higher perceived stress (feelings of lack of control)
Edinburgh Postnatal Depression Scale (EPDS)	As a continuous measure (0-30) where a higher score indicates a higher probability of depression
Behavioural response to pregnancy scale	Two subscales: 1. Limiting/resting behaviour (0-20)[a] **2.** All-or-nothing behaviour (0-28)[b]

[a]***Limiting response includes:*** *avoiding exercise, life on hold, avoiding usual activities, going to bed during the day, not being able to do usual level of activities.*

[b]***All-or-nothing response includes:*** *overdoing and needing to rest, pushing oneself, carrying on as normal, doing too much.*

Adapted from McCarthy et al (McCarthy et al., 2015)

Table 16: Associations between participant characteristics and vigorous physical activity

Vigorous physical activity (exercise which made you breathe harder or pant)

Correlation between social characteristics and vigorous physical activity

	Vigorous	Age	Education	Ethnicity	Marital status	Employment	Accommodation	Socioeconomic
Vigorous	1.0000							
Age	0.0161	1.0000						
Education	0.0488	0.1312	1.0000					
Ethnicity	0.0332*	0.0622	0.3092	1.0000				
Marital status	-0.0202	0.3563	0.0183	-0.0411	1.0000			
Employment	0.0299	0.2580	0.1485	0.0559	0.2750	1.0000		
Accommodation	0.0287*	0.4035	0.3094	0.1819	0.4039	0.2848	1.0000	
Socioeconomic	0.0071*	0.2277	0.0954	-0.0701	0.1659	-0.0757	0.2010	1.0000

Correlation between biological characteristics and vigorous physical activity

	Vigorous	Gravidity	Maternity service	Delivery	BMI
Vigorous	1.0000				
Gravidity	-0.0148	1.000			
Maternity service	-0.0015	-0.0131	1.000		
Delivery	0.0192	-0.0249	0.1198	1.0000	
BMI	0.0127	0.0417	0.0853	-0.1091	1.0000

Correlation between psychological and behavioural measures and vigorous physical activity

	Vigorous	Smoking	Alcohol	Folate	Five a day	Fish	Anxiety	Stress Scale	Limiting	All or nothing	Depression scale
Vigorous	1.0000										
Smoking	-0.0233	1.0000									
Alcohol	0.0731*	0.1695	1.0000								
Folate	0.0145	-0.2829	-0.0607	1.0000							
Five a day	0.1133*	-0.0486	-0.0179	0.0160	1.0000						
Fish	0.0822*	-0.0136	0.0235	0.0245	0.0850	1.0000					
Anxiety	0.0225	0.1123	0.0681	-0.1748	-0.0086	-0.0166	1.0000				
Stress Scale	0.0550	0.1324	0.0254	-0.1616	-0.0456	0.0212	0.5724	1.0000			
Limiting	-0.1216*	-0.0221	-0.0467	0.0054	-0.0743	-0.0419	0.2162	0.2944	1.0000		
All or nothing	0.1404*	0.0124	0.0576	-0.0543	0.0244	0.0019	0.2179	0.2877	0.0759	1.0000	
Depression scale	0.0337	0.1326	0.0374	-0.1994	-0.0481	-0.0013	0.6223	0.7313	0.3485	0.2840	1.0000

***P-value <0.05**

Table 17: Associations between participant characteristics and moderate physical activity

Moderate physical activity (exercise which did not make you breathe harder or pant)

Correlation between social characteristics and moderate physical activity

	Moderate	**Age**	**Education**	**Ethnicity**	**Marital status**	**Employment**	**Accommodation**	**Socioeconomic**
Moderate	1.0000							
Age	0.1176*	1.0000						
Education	0.0792*	0.1312	1.0000					
Ethnicity	0.0895*	0.0622	0.3092	1.0000				
Marital status	0.0948*	0.3563	0.0183	-0.0411	1.0000			
Employment	0.0391	0.2580	0.1485	0.0559	0.2750	1.0000		
Accommodation	0.1143*	0.4035	0.3094	0.1819	0.4039	0.2848	1.0000	
Socioeconomic	0.0795*	0.2277	0.0954	-0.0701	0.1659	-0.0757	0.2010	1.0000

Correlation between biological characteristics and moderate physical activity

	Moderate	**Gravidity**	**Maternity service**	**Delivery**	**BMI**
Moderate	1.0000				
Gravidity	-0.0316	1.000			
Maternity service	-0.0685*	-0.0131	1.000		
Delivery	0.0219	-0.0249	0.1198	1.0000	
BMI	-0.0111	0.0417	0.0853	-0.1091	1.0000

Correlation between psychological and behavioural measures and moderate physical activity

	Moderate	Smoking	Alcohol	Folate	Five a day	Fish	Anxiety	Stress Scale	Limiting	All or nothing	Depression scale
Moderate	1.0000										
Smoking	-0.0687*	1.0000									
Alcohol	0.0492*	0.1695	1.0000								
Folate	0.0833*	-0.2829	-0.0607	1.0000							
Five a day	0.1111*	-0.0486	-0.0179	0.0160	1.0000						
Fish	0.0589	-0.0136	0.0235	0.0245	0.0850	1.0000					
Anxiety	-0.0885*	0.1123	0.0681	-0.1748	-0.0086	-0.0166	1.0000				
Stress Scale	-0.0735*	0.1324	0.0254	-0.1616	-0.0456	0.0212	0.5724	1.0000			
Limiting	-0.1990*	-0.0221	-0.0467	0.0054	-0.0743	-0.0419	0.2162	0.2944	1.0000		
All or nothing	0.0290	0.0124	0.0576	-0.0543	0.0244	0.0019	0.2179	0.2877	0.0759	1.0000	
Depression scale	-0.1033*	0.1326	0.0374	-0.1994	-0.0481	-0.0013	0.6223	0.7313	0.3485	0.2840	1.0000

***P-value <0.05**

Table 18: Associations between participant characteristics and recreational walking

Recreational walking (*walking for recreation or exercise)*

Correlation between social characteristics and recreational walking

	Recreational walking	Age	Education	Ethnicity	Marital status	Employment	Accommodation	Socioeconomic
Recreational walking	1.0000							
Age	0.0869*	1.0000						
Education	0.0494	0.1312	1.0000					
Ethnicity	0.0789*	0.0622	0.3092	1.0000				
Marital status	0.0516*	0.3563	0.0183	-0.0411	1.0000			
Employment	-0.0333	0.2580	0.1485	0.559	0.2750	1.0000		
Accommodation	0.0801*	0.4035	0.3094	0.1819	0.4039	0.2848	1.0000	
Socioeconomic	0.0696	0.2277	0.0954	-0.0701	0.1659	-0.0757	0.2010	1.0000

Correlation between biological characteristics and recreational walking

	Recreational walking	Gravidity	Maternity service	Delivery	BMI
Recreational walking	1.0000				
Gravidity	-0.0339	1.000			
Maternity service	-0.0207	-0.0131	1.000		
Delivery	0.0290	-0.0249	0.1198	1.0000	
BMI	-0.0212	0.0417	0.0853	-0.1091	1.0000

Correlation between psychological and behavioural measures and recreational walking

	Recreational walking	Smoking	Alcohol	Folate	Five a day	Fish	Anxiety	Stress Scale	Limiting	All or nothing	Depression scale
Recreational walking	1.0000										
Smoking	-0.0688*	1.0000									
Alcohol	0.0335	0.1695	1.0000								
Folate	0.0670*	-0.2829	-0.0607	1.0000							
Five a day	0.1007*	-0.0486	-0.0179	0.0160	1.0000						
Fish	0.0649*	-0.0136	0.0235	0.0245	0.0850	1.0000					
Anxiety	-0.08741*	0.1123	0.0681	-0.1748	-0.0086	-0.0166	1.0000				
Stress Scale	-0.0631*	0.1324	0.0254	-0.1616	-0.0456	0.0212	0.5724	1.0000			
Limiting	-0.2514*	-0.0221	-0.0467	0.0054	-0.0743	-0.0419	0.21262	0.2944	1.0000		
All or nothing	0.0112	0.0124	0.0576	-0.0543	0.0244	0.0019	0.2179	0.2877	0.0759	1.0000	
Depression scale	-0.0887*	0.1326	0.0374	-0.1994	-0.0481	-0.0013	0.6223	0.7313	0.3485	0.2840	1.0000

***P-value <0.05**

Table 19: Multinomial logistic regression for vigorous physical activity

Variable	**Vigorous physical activity**	
	At least once a wk[a] (n =484)	**At least once a day[a] (n= 15)**
Age category		
<25 years	1	1
25-29 years	1.23 (0.76-2.1)	0.31 (0.54-1.76)
30-34 years	1.53 (0.92-2.53)	0.12 (0.16-0.95)
≥ 35 years	1.02 (0.58-1.81)	0.38 (0.45-3.16)
Ethnicity		
Non- Caucasian	1	1
Caucasian	1.23 (0.50-3.1)	n/a
Marital status		
Single	1	1
Married/partner	0.53 (0.34-0.83)	n/a
Education		
Schooling ≤12 years	1	1
Schooling >12 years	1.16 (0.80-1.71)	1.45 (0.27-7.75)
Employment status		
Not working	1	1
Working	1.13 (0.74-1.71)	0.81 (0.13-5.07)
Accommodation		
Other	1	1
Own house	1.08 (0.81-1.45)	0.62 (0.17-2.32)
Socioeconomic		
<24	1	1
≥24	1.18 (0.86-1.62)	0.55 (0.16-1.89)
Maternity service[b]		
Private	1	1
Public	1.08 (0.82-1.41)	1.13 (0.26-4.86)
BMI category[d]		
Normal	1	1
Overweight	0.96 (0.75-1.23)	0.76 (0.21-2.67)
Obese	1.37 (0.98-1.92)	1.09 (0.20-5.77)
Gravidity[b]		
1 pregnancy	1	1
>1 Pregnancy	0.93 (0.68-1.27)	5.81 (1.89-17.91)
Smoking		
Smokers	1	1
Non-smokers	1.28 (0.98-1.68)	0.86 (0.25-2.98)
Alcohol		
Drinkers	1	1
Non-drinkers	0.69 (0.51-0.93)	0.40 (0.07-2.15)
Folic-acid[b]		
No	1	1
Yes	1.10 (0.83-1.46)	1.73 (0.43-7.01)
Five a day[b]		
No	1	1
Yes	1.66 (1.23-2.23)	2.61 (0.73-9.39)
Fish[b]		
No	1	1
Yes	1.41 (1.12-1.77)	1.17 (0.38-3.61)
Anxiety Index	1.00 (1.00-1.01)	1.01 (1.00-1.01)
Stress	10.2 (0.99-1.04)	1.11 (1.00-1.24)
Depression Scale	1.01 (0.98-1.05)	0.93 (0.80-1.10)
Limiting	0.92 (0.90-0.95)	0.84 (0.75-0.94)
All or nothing	1.06 (1.03-1.08)	1.14 (1.03-1.26)

*RRR (95%, CI) *P;* n/a – not applicable (two little numbers on the cells); Includes only variables collected at 15±1 weeks' gestation (mode of delivery excluded)*;* [a]Reference category: never vigorously physically active; [b]Missing values; [c]1 denotes reference category; [d]BMI category defined as World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2); n/a, small numbers

Table 20: Multinomial logistic regression for moderate physical activity

Variable	Moderate physical activity	
	At least once a wk[a] (n =1145)	At least once a day[a] (n= 181)
Age category		
<25 years	1	1
25-29 years	1.81 (1.16-2.81)	1.41 (0.67-2.96)
30-34 years	1.73 (1.08-2.76)	1.87 (0.86-4.06)
≥ 35 years	1.64 (0.96-2.82)	2.02 (0.85-4.80)
Ethnicity		
Non- Caucasian	1	1
Caucasian	1.38 (0.67-2.84)	6.15 (0.75-50.10)
Marital status		
Single	1	1
Married/partner	1.31 (0.85-2.03)	0.89 (0.44-1.82)
Education		
Schooling ≤12 years	1	1
Schooling >12 years	1.49 (1.04-2.13)	1.24 (0.69-2.22)
Employment status		
Not working	1	1
Working	1.17 (0.79-1.74)	0.65 (0.35-1.19)
Accommodation		
Other	1	1
Own house	0.91 (0.67-1.24)	1.08 (0.66-1.77)
Socioeconomic		
<24	1	1
≥24	1.61 (1.18-2.20)	1.53 (0.92-2.55)
Maternity service[b]		
Private	1	1
Public	0.77 (0.57-1.04)	1.20 (0.75-1.91)
BMI category[d]		
Normal	1	1
Overweight	1.09 (0.83-1.41)	0.85 (0.56-1.29)
Obese	1.27 (0.88-1.83)	0.78 (0.42-1.43)
Gravidity[b]		
1 pregnancy	1	1
>1 Pregnancy	0.92 (0.67-1.27)	1.37 (0.85-2.21)
Smoking		
Smokers	1	1
Non-smokers	1.27 (0.96-1.67)	1.34 (0.86-2.08)
Alcohol		
Drinkers	1	1
Non-drinkers	0.69 (0.51-0.92)	0.87 (0.55-1.38)
Folic-acid[b]		
No	1	1
Yes	1.05 (0.78-1.41)	1.17 (0.73-1.87)
Five a day[b]		
No	1	1
Yes	1.48 (1.02-2.14)	1.97 (1.19-3.27)
Fish[b]		
No	1	1
Yes	1.22 (0.95-1.58)	1.19 (0.80-1.75)
Anxiety Index	1.00 (1.00-1.01)	1.00 (0.98-1.001)
Stress	1.01 (0.98-1.03)	1.02 (0.98-10.6)
Depression Scale	1.00 (0.96-1.04)	0.98 (0.92-1.04)
Limiting	0.93 (0.90-0.96)	0.86 (0.82-0.90)
All or nothing	1.02 (0.99-1.04)	1.07 (1.03-1.12)

*RRR (95%, CI) *P;* n/a – not applicable (two little numbers on the cells); Includes only variables collected at 15±1 weeks' gestation (mode of delivery excluded)*;* [a]Reference category: never moderately physically active; [b]Missing values; [c]1 denotes reference category; [d]BMI category defined as World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2)

Table 21: Multinomial logistic regression for recreational walking

Variable	Recreational walking	
	At least once a wk[a] (n =1388)	At least once a day[a] (n= 170)
Age category		
<25 years	1	1
25-29 years	0.94 (0.52-1.68)	1.73 (0.70-4.29)
30-34 years	0.71 (0.38-1.31)	1.60 (0.62-4.15)
≥ 35 years	1.04 (0.49-2.17)	2.36 (0.80-6.95)
Ethnicity		
Non- Caucasian	1	1
Caucasian	2.02 (0.83-4.91)	3.54 (0.65-19.2)
Marital status		
Single	1	1
Married/partner	1.34 (0.77-2.34)	0.63 (0.28-1.45)
Education		
Schooling ≤12 years	1	1
Schooling >12 years	1.20 (0.76-1.90)	1.29 (0.64-2.61)
Employment status		
Not working	1	1
Working	0.61 (0.34-1.10)	0.23 (0.11-0.49)
Accommodation		
Other	1	1
Own house	1.02 (0.68-1.52)	1.20 (0.68-2.14)
Socioeconomic		
<24	1	1
≥24	1.47 (0.98-2.21)	1.56 (0.85-2.87)
Maternity service[b]		
Private	1	1
Public	0.95 (0.64-1.41)	1.14 (0.67-1.94)
BMI category[d]		
Normal	1	1
Overweight	1.52 (1.07-2.17)	1.41 (0.86-2.31)
Obese	1.81 (1.07-3.06)	1.02 (0.47-2.19)
Gravidity[b]		
1 pregnancy	1	1
>1 Pregnancy	0.89 (0.60-1.33)	0.81 (0.44-1.47)
Smoking		
Smokers	1	1
Non-smokers	1.69 (1.19-2.40)	2.12 (1.26-3.56)
Alcohol		
Drinkers	1	1
Non-drinkers	0.89 (0.60-1.31)	1.04 (0.60-1.79)
Folic-acid[b]		
No	1	1
Yes	1.28 (0.88-1.87)	1.53 (0.88-2.65)
Five a day[b]		
No	1	1
Yes	1.78 (1.03-3.07)	2.88 (1.50-5.52)
Fish[b]		
No	1	1
Yes	1.52 (1.07-2.16)	1.64 (1.02-2.62)
Anxiety Index	1.00 (0.98-1.01)	1.01 (0.98-1.01)
Stress	1.00 (0.97-1.03)	1.02 (0.97-1.07)
Depression Scale	1.02 (0.97-1.07)	1.01 (0.93-1.07)
Limiting	0.89 (0.55-0.93)	0.81 (0.76-0.85)
All or nothing	1.01 (0.98-1.05)	1.06 (1.01-1.11)

*RRR (95%, CI) *P;* n/a – not applicable (two little numbers on the cells); Includes only variables collected at 15±1 weeks' gestation (mode of delivery excluded)*;* [a]Reference category: never recreationally walking; [b]Missing values; [c]1 denotes reference category; [d]BMI category defined as World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2)

Table 22: Unadjusted associations for moderate or high levels of physical activity levels

Variable	Physical Activity Subgroups			
	Moderate[a] (n =960)		High[a] (n= 413)	
Age category				
<25 years	1[d]		1	
25-29 years	2.35 (1.63-3.41)	0.000	2.02 (1.26-3.22)	<0.0001
30-34 years	2.70 (1.89-3.85)	0.000	3.07 (1.97-4.78)	<0.0001
≥ 35 years	2.48 (1.58-3.89)	0.000	2.62 (1.52-4.54)	<0.0001
Ethnicity				
Non-Caucasian	1		1	
Caucasian	1.62 (0.84-3.13)	0.155	5.42 (1.56-18.88)	<0.0001
Marital status				
Single	1		1	
Married/partner	2.17 (1.54-3.07)	0.000	2.03 (1.54-3.07)	<0.0001
Education				
Schooling ≤12 years	1		1	
Schooling >12 years	2.09 (1.52-2.88)	0.000	1.96 (1.32-2.90)	<0.0001
Employment status				
Not working	1		1	
Working	2.07 (1.44-2.96)	0.000	1.28 (0.86-1.91)	0.230
Accommodation				
Other	1		1	
Own house	1.72 (1.35-2.19)	0.000	1.77 (1.35-2.36)	<0.0001
Socioeconomic index				
<24	1		1	
≥24	1.65 (1.23-2.21)	0.001	1.73 (1.21-2.47)	<0.0001
Maternity service[b]				
Private	1		1	
Public	0.61 (0.46-0.82)	0.001	0.65 (0.47-0.92)	<0.0001
BMI category[e]				
Normal	1		1	
Overweight	1.08 (0.83-1.42)	0.559	0.99 (0.73-1.36)	0.973
Gravidity[b]				
1 pregnancy	1		1	
>1 Pregnancy	0.82 (0.60-1.13)	0.221	0.90 (0.62-1.31)	0.592
Mode of delivery[c]				
C-section	1		1	
Vaginal birth	0.95 (0.73-1.24)	0.732	1.11 (0.81-1.52)	0.512
Smoking				
Smoker	1		1	
Non-smoker	1.56 (1.21-2.01)	0.001	1.65 (1.22-2.24)	<0.0001
Alcohol				
Drinker	1		1	
Non-drinker	0.63 (0.48-0.83)	0.001	0.67 (0.48-0.94)	<0.0001
Folic-acid supplement[b]				
No	1		1	
Yes	1.59 (1.24-2.03)	0.000	1.68 (1.25-2.26)	<0.0001
Five a day[b]				
No	1		1	
Yes	1.57 (1.07-2.32)	0.022	2.30 (1.51-3.50)	<0.0001
Fish[b]				
No	1		1	
Yes	1.41 (1.08-1.84)	0.012	1.60 (1.18-2.17)	<0.0001
Anxiety Index	0.99 (0.98-1.00)	0.003	0.99 (0.98-1.00)	<0.0001
Perceived Stress Scale	0.98 (0.97-1.00)	0.084	0.97 (0.95-1.00)	<0.0001
Depression Scale	0.96 (0.94-0.99)	0.003	0.94 (0.95-0.97)	<0.0001
Limiting response	0.94 (0.91-0.96)	0.000	0.86 (0.83-0.89)	<0.0001
All or nothing response	1.02 (1.00-1.04)	0.215	1.02 (0.99-1.05)	0.260

[a]Reference category: low physical activity level; [b]Missing values; [c]Recoded at birth [d]1 denotes reference category [e]BMI category World Health Organisation guidelines as underweight (<18.5kg/m^2), normal weight (18.5 -24.9kg/m^2), overweight (≥25 – 29.9kg/m^2), obese (≥30kg/m^2)

9 APPENDIX B: SUPPLEMENTARY MATERIAL STUDY 2 & 3

Ethical Approval Form for paper 2 and paper 3

UCC

Tel: + 353-21-490 1901
Fax: + 353-21-490 1919

Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

COISTE EITICE UM THAIGHDE CLINICIÚIL
Clinical Research Ethics Committee

Lancaster Hall,
6 Little Hanover Street,
Cork,
Ireland.

Our ref: ECM 4 (y) 06/01/15 & ECM 3 (ccc) 03/11/15

22nd October 2015

Professor Patricia Kearney
Department of Epidemiology & Public Health
University College Cork
4th Floor
Western Gateway Building
Western Road
Cork

Re: Experiences of lifestyle management and support during pregnancy: a qualitative study of the attitudes and experiences of pregnant women and healthcare professionals.

Dear Professor Kearney

The Chairman approved the following:

- Amendment Application Form signed 19th October 2015
- Revised Protocol Submission Form Version 5 dated 19th October 2015
- Study Protocol Version 3 dated 19th October 2015.

Yours sincerely

Professor Michael G Molloy
Chairman
Clinical Research Ethics Committee
of the Cork Teaching Hospitals

Copy to Caragh 24.11.15

The Clinical Research Ethics Committee of the Cork Teaching Hospitals, UCC, is a recognised Ethics Committee under Regulation 7 of the European Communities (Clinical Trials on Medicinal Products for Human Use) Regulations 2004, and is authorised by the Department of Health and Children to carry out the ethical review of clinical trials of investigational medicinal products. The Committee is fully compliant with the Regulations as they relate to Ethics Committees and the conditions and principles of Good Clinical Practice.

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Clinical Research Ethics Committee

Lancaster Hall,
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Our ref: ECM 4 (y) 06/01/15

17th December 2014

Professor Patricia Kearney
Department of Epidemiology & Public Health
University College Cork
4th Floor
Western Gateway Building
Western Road
Cork

Re: Experiences of lifestyle management and support during pregnancy: a qualitative study of the attitudes and experiences of pregnant women and healthcare professionals.

Dear Professor Kearney

Expedited approval is granted to carry out the above study at:

- Cork University Maternity Hospital and University College Cork.

The following documents have been approved.

- Signed Application Form
- CV for Chief Investigator
- Study Advertisement
- Topic Guides
- Participant Information Sheets Version 1 dated 25th November 2014
- Consent Forms
- Study Protocol.

We note that the co-investigators involved in this study will be:

- Dr Sheena McHugh, Post-Doctoral Researcher, Ms Emma Clifford, Dietitian and Caragh Flannery, HRB SPHERE Student

Yours sincerely

Micheál G Molloy

Professor Michael G Molloy
Chairman
Clinical Research Ethics Committee
of the Cork Teaching Hospitals

The Clinical Research Ethics Committee of the Cork Teaching Hospitals, UCC, is a recognised Ethics Committee under Regulation 7 of the European Communities (Clinical Trials on Medicinal Products for Human Use) Regulations 2004, and is authorised by the Department of Health and Children to carry out the ethical review of clinical trials of investigational medicinal products. The Committee is fully compliant with the Regulations as they relate to Ethics Committees and the conditions and principles of Good Clinical Practice.

Enablers and barriers to physical activity in overweight and obese pregnant women: an analysis informed by the Theoretical Domains Framework and COM-B model (Study 2)

Patient Information Sheet

Experiences of lifestyle management and support during pregnancy   **Patient Information Sheet**

Principle Investigators: Prof. Patricia Kearney, Dr Sheena Mc Hugh
Study team: Emma Clifford, Caragh Flannery
Address: Department of Epidemiology & Public Health, 4th Floor Western Gateway, University College Cork.

Introduction
You are invited to take part in this study to explore women's experiences of lifestyle management and advice during pregnancy. It is completely up to you to decide whether you wish to participate in this study. Your future care will not be affected if you decide not to take part. This leaflet gives detailed information about the research study, which will be discussed with you. Once you understand the study, you will be asked to sign this form if you wish to participate.

About the study
Pregnancy is time of physical, social and emotional transition. It is also a time in which a lot of information and advice is given. It is important that we learn more about the challenges of maintaining a healthy lifestyle during pregnancy in order to support women and improve the advice and resources available. The aim of this study is to explore the opportunities for and challenges to engaging in healthy eating and physical activity during pregnancy. The study is funded by the Health Research Board in Ireland. We are inviting you to take part in an interview which will last between 30 and 40 minutes. During this time you will be asked about your own pregnancy(s), your interactions with health care professionals and what you think about different ways of supporting health lifestyle behaviours. You can select a suitable time, date and location for the interview and one of our team will travel to meet you. If it is agreeable with you, the interview will be recorded by the researcher to assist with recording the information.

Benefits & Risks
We hope that the results of this study will be used to develop more effective interventions and improve the resources and services available to women during pregnancy. The interview will be an opportunity for you to share your experiences and provide feedback on the best ways to support women in relation to lifestyle management during pregnancy. We do not anticipate any risks.

Participation

Taking part in this study is voluntary. If you agree to take part you are free to withdraw from the study at any time without having to give a reason. This will not impact on your future health care. As a token of our appreciation you will be given a €20 voucher for participating in the study.

Confidentiality

No material which could personally identify you will be used in any reports on this study.

Any identifiable information will be removed from the interview transcripts so all data will be anonymised. A unique study number will be assigned to tapes and transcripts to ensure the confidentiality of any records we keep. Information will be stored securely on password protected computers in the Department of Epidemiology & Public Health in University College Cork. Only members of the research team named on form will have access to the data. In accordance with the Data Protection Act the interview transcripts will be kept for 7 years after which time they will be deleted.

Results

The study results will be published in medical journals and will be available from the research team.

General Information

More information about the study can be obtained from any member of the research team. You do not have to answer all the questions asked during the interview and you may stop the interview at any time.

Statement of Approval

This study has received ethical approval from the Cork University Hospitals Research Ethics Committee**.**

Patient Consent Form

Experiences of lifestyle management and support during pregnancy
Consent Form

Principle Investigators: Prof. Patricia Kearney, Dr Sheena Mc Hugh
Study team: Emma Clifford, Caragh Flannery
Address: Department of Epidemiology & Public Health, 4th Floor Western Gateway, University College Cork.
Email: s.mchugh@ucc.ie , cflannery@ucc.ie

- I confirm that the research project and the interview have been fully explained to me.
- I have read and understood the Information Sheet and have had an opportunity to ask questions about the project, to which I have had satisfactory answers.
- I am aware that participation is ***voluntary*** and that I may withdraw my consent at any time without having to give a reason.
- I am aware that my decision not to participate or to withdraw will not have any personal consequences for me.
- Confidentiality of records concerning my involvement in this project will be maintained in an appropriate manner. When required by law, the records of this research may be reviewed by government agencies and sponsors of the research.
- I understand that the sponsors and investigators have such insurance as is required by law in the event of injury resulting from this research.
- I have received a copy of this consent form and the participant information sheet for my records.

I, the undersigned, hereby consent to being a participant in the above described study conducted at the University College Cork. I understand that if I have any questions concerning this research, I can contact the researcher listed above. If I have further queries concerning my rights in connection with the research, I can contact the Clinical Research Ethics Committee of the Cork Teaching Hospitals, Lancaster Hall, 6 Little Hanover Street, Cork. After reading the entire consent form, if you have no further questions about giving consent, please sign where indicated.

…………………………………	…………………………………	…………………………
Participant Signature	Name in Block Capitals	Date
…………………………………	…………………………………	…………………………
Researcher Signature	Name in Block Capitals	Date

Table 23: Coding frame – Barriers and enablers to physical activity

COM-B component	Relevant TDF domain that map onto the COM_B	Codes mapped to TDF framework	Example of quotation (s) Enablers	Example of quotation (s) Barriers
Physical capability – physical skill, strength, stamina	**Physical skills**	- Fitness level prior to pregnancy - House work as a form of PA - Medical conditions and pregnancy symptoms (pain, energy, tiredness)	Benefit: *'I would go back to swimming. It makes you feel so much lighter. It's great to feel that way' (PW16)* Benefit: '*It's just enjoyable and helpful [aqua aerobics], that's probably why I didn't feel so pregnant. I didn't have any back issues, all my muscles were working and you concentrate on your breathing as well' (PW16)* Benefit: *'Like it actually wakes me up….I do get energy after it, like if I go from my walk, I am well able to clean the house whereas it I don't go for my walk I am just thrown there' (PW15)* Benefit: *'A couple of days ago I was exhausted and I was just like no, I should just get out and get some air and it was actually so much better to get out, I felt so much better than sitting around the house, it's good for your mental health as well. Definitely' (PW13)* Benefit: *'Swimming, I would love to do more swimming because it takes the pressure off the bump. I had fierce pressure. Even with the pelvic girdle pain if I stayed in the pool it took the pressure off' (PW18)* Benefit: *'I always feel good after a walk, like I*	Medical: *'I do go for a walk once in a while, because of the pelvic pain it is very difficult for me I feel pain every time I go for walk so I don't go all the time' (PW25)* Medical: *'I suppose I could walk a bit more. You see I'm getting physio at the moment…I have SPD. I have Pain in my pubic area. So I supposed to do fewer activities' (PW04)* Medical: *'I did have a little bit of swelling in the feet after work and you are coming and resting , its adjusting' (PW14)* Medical: *'The problems I had just stopped me [PA]. Like I got a polyp…which was heavy bleeding and the more I strained the body, even just a swim it was just like there was more pressure on it so I just said it was better to cut everything' (PW15)* Medical: *'I'm a high risk pregnancy so I couldn't do any of the exercise then on this pregnancy. And then I have factor 5 blood so I really clotting and all that, I have to take it easy' (PW05)* Energy: *'It harder now to move faster now that I am pregnant. Like sometimes I have energy and someday I don't… It's difficult, like you feel like you want to do stuff but you can't, your body is just*

			wouldn't go for a long' (PW20) Housework: *'No I wouldn't get out and walk or anything like that….housework would be my activity during the day'(PW04)* Housework: *'Not really, there's nothing really, I'm not a big fan of exercise. I will do the house work, the cleaning and the cooking' (PW17)* Fitness: *'I don't know I think it depends on everyone's circumstances. Like a lot of women would be fit before they got pregnant and they would keep up their walking or running' (PW01)*	*tired and drained physically' (PW20)* Energy: *'Getting on the cross trainer but after a half hour I was just like, I was pretty exhausted and the next day was pretty bad, my energy levels just aren't what they used to be' (PW13)*
Psychology capability – knowledge or psychological skills, strength or stamina to engage in the necessary mental process	**Knowledge** (Awareness of the existence of something – including knowledge of condition/ scientific rationale, procedural knowledge. Knowledge of task environment)	- Limited knowledge of PA benefits, types of PA in pregnancy and PA resources - Pregnant women discussed concerns around having that 'conversation'	PA knowledge: *'I suppose being pregnant doesn't stop you from doing exercises if you are used to doing exercise, you have to continue doing it but you have to know which one is good in your condition. This is what will be the challenge' (PW28)* PA knowledge*: 'I think there is enough information* [PA], *people do give u information it's just to, it's just to go out and ehhhh (laughing) do it! I think once you start its ok but the thought of it is actually worse' (PW08)* PA knowledge*: 'I suppose like yeah pregnancy is difficult and you would be tired, but it's not a disease like (laughter), like I'd still continue to walk' (PW09)* PA benefits: *'I think it's important to be active of course to keep your muscles strong for the labour*	PA knowledge: *'And I even with the risk it's just the nervousness that you don't want to be doing physical activity or something like that. And then you're scared of your life that you're after doing something' (PW05).* PA knowledge: *'I had just signed up for them* [classes] *and then I was, got pregnant. Then I was thinking can I do them. And I was thinking can I do the zumba but I was think there is too much jumping and dancing in that' (PW05).* PA knowledge: '*Like in the gym with other people sometimes it could be a bit dangerous cause people can be working out around you and might hit you so somewhere specially for pregnant women' (PW03)* PA knowledge: *'I mean I don't know can you do certain exercises so I would be worried that I could*

			and everything' (PW04) PA benefits: *'If there is something light or some kind of pregnancy classes. Tailored for pregnancy, I think it would be great for people. It gets, it gets, it helps with your preparation for the birth and all that stuff' (PW 05)* PA resources: *'I think that would be a good idea* [PA information & resources], *like if you were given like numbers and sort of classes around that area at your clinic appointments for; like types of yoga and stuff like that' (PW04)* The conversation: *'I suppose it all about having the conversation, it about being given the right information especially around the first scan' (PW19).*	*pull a muscle so I would be extra cautious I suppose at the gym cause I afraid and I wouldn't really know what, like I think did ask at one stage like about what I should and shouldn't be doing but she said do what you normally do but just take it easy (laughs) that's the advice I got so like it's not really helpful at all' (PW13)* PA knowledge: *'Cause often when you in the gym on your own and you're not really sure, like I know you're not supposed to lift heavy weight unless you have a help especially if you're not used to it but [am] the rowing machine, can you use than when you are pregnant?' (PW13)* PA knowledge: *'To be honest, I'm not good in what physical activities a pregnant woman should do because nobody really has told me about the kind of exercise you should be doing' (PW28).* PA knowledge: *'Like I know the services are fantastic and they're brilliant and if there are any problems they are in there like a bullet out of a gun but I think it's the smaller things that they oversee* [lifestyle information]*' (PW18)* PA knowledge: *'what I found different was when they know that you have children already they kind of thinking that you know everything which is not true…you may forget, years apart, like between now and the last time I had a baby there is a three years gap so I can't remember everything but they seem to assume because you have had other children you know already what to do' (PW28)*

				PA resources: *'I have, I never really got information about classes around. I seem to have to seek it out myself. And I ended up never going to do that, you know what I mean' (PW04)* The conversation: '*All the little things, it was more a checklist than an actual conversation. Obviously it was like I need to discuss this, this, this based on whatever the chart or folder says but it was more of a checklist thing rather than a conversation' (PW16)* The conversation: *'It's very limited really, very limited. It's a quick one minute conversation really in relation to it [PA/Diet]. I would have done a good bit more research myself, the first time round in terms of what to avoid and what's important in terms of baby as well….I suppose nobody really sits you down to go through the implications of that or the benefits and stuff like that.(PW21)* The conversation: *'there's no such thing a really showing you or describing it ya know, or making sure that you are doing, I think that could be discussed or checked a little bit more' (PW14)* Tech: *'I feel the internet [for information] can be great but it can also be the worst thing in the world because your almost self-diagnosing yourself with every single issue that you might not even have so I do think it should be a little bit more relevant to the person' (PW14)*
	Behaviour	- Self- monitoring,	Use of technology: *'Like I hear of step counter for*	Use of technology: '*Maybe for some people it*

	Regulation & Goals* (managing or changes action – self-monitoring, breaking habits or action planning) -	use of pedometer/ step count - Women expressed interest in goal setting	*number of steps and stuff like that and I think that would be great, I think it would motivate you, you know' (PW10)* Use of technology: *'I think pedometers are great, of course I don't have one myself (laughs) but (amm) I think they are brilliant cause (amm) you know how far you have walked in a day and how many calories which is great' (PW13)* Use of technology: *'If there was definitely some sort of measurement like a pedometer or something like that, just something that would flag where you are at and what your targets should be' (PW21)* Use of technology: *'People who have an apple watch, they will get a buzz and it will tell them to stand up for a bit and I was like seriously but that's the way it works. Reminding you to exercise and stuff like that….I mean technology, it has such a big place in our lives and it's not the end, if we could do something it would be good but (emm) I don't know it's all about how you promote it and how visual and how people take to it' (PW16)* Use of technology: *'If you can link it together, how much exercise you should do, what food, how many calories every day and you can track or like today I did less exercise so tomorrow I have to do the amount I should be doing' (PW03)* Goals: *'I guess if you had a goal and you had it in your mind that would help you be healthier'*	*might, because it is kind of a big brother as well [tracking]. It wouldn't be for me, but for some people it might be an issue. If you had weight problems, you know someone saying "keep a track of it"' (PW27)* Use of technology: *'I could see how some people would think that like big brother is watching you and they might not like it (laughing)' (PW08)* Use of technology: *'Check up on me [phone app tracking].....I wouldn't like that, that invasion of privacy. If the person feels like they can't be responsible for their pregnancy of course but you'd have to be completely stupid to not be able to do it yourself or take responsibility. You should be able to look after your own pregnancy' (PW19)* Use of technology: *'I'm not actually that good of keeping track of anything really like that [laughs] I would try to write things down but I would just be so busy or I would forget and I wouldn't do it, so I wouldn't be a good user of those [pregnancy] apps' (PW13)* Use of technology: *Yeah if I was supposed to be doing it probably would be more of a burden, I'd be going "oh for god sake I've to sit down now and do that" rather than having it for your own personal, tracking I suppose…… if it was seen as more of a homework thing [tracking PA in app] I'd be less likely to use, do it' (PW07)* Goals: *…well I would say goals instead of targets*

			(PW14) Goals: *'I am very goal driven, I would love that, if someone said ' you need to walk three miles this week and you need to do four laps of the pool and something else' you know you would hit your targets and you know then that even if they say that was helping you, that you are going a good job. You're doing something good anyway' (PW18)*	*anyways. I think targets might push it over the edge, I think we should use the words goals instead, so goals you have to try reach. I guess if you had a goal and you had it in your mind that I would help you be healthier than ya'*
Physical Opportunity – Opportunity afforded by the environment involving time, resources, location, cues physical affordance	**Environmental context and resources** (persons situation or environment – environmental stressors, resources, material resources, organisational culture, climate, salient events critical incidents, interactions, barriers and facilitators)	- Pregnant woman's situation (family life/children/wor k/pets) - Financial situation - Weather/ built environment and resources within the community	Financial & resource: *'I mean jokes aside anything financially viable. If you were to, I don't know maybe because you are pregnant you pay half price or something like that so that people would go [gym]' (PW16)* Financial & resource: *'Free gym membership for pregnant woman for 9 months (laughs) that would be great, even I would go then (laughs)' (PW16)* Pets: *'…we have pets at home and we would take them for a walk, felt like we had too' (PW01)* Pets: *'I have dog so I do take her out for a walk. Have to bring the little dog out [laughter]. Ya know a little westie' (PW05)*	No time: *'It's very hard to just get time to go [swimming]. I find that anyway….when you are busy and you have commitments and stuff. I find it very tough to get out' (PW18)* No time: *'I manage the home like and between everything I just don't get around to it, it would stop me from being active. I never really have time to myself, like your trying to get things done for the baby, then you're trying to involve the kids so that there not feeling left out, so it is very hard' (Pw10)* No time: *'I suppose prior to the first pregnancy I could go from work to exercise and then come home. Whereas, now if I do that I don't see my son before he goes to bed. So I just can't fit it into my day to be honest, it's more challenging' (PW21)* No time: *'I don't have any time as I work full, I leave my house at half seven in the morning and come back at five in the evening so it's time to look after the children. There's no really time for physical exercise' (PW28)*

				Financial: *'I mean I'm not going just because I have two kids I have a massive big mortgage and I actually can't afford the full membership to go swimming and that's the only reason why' (PW16)* Resources: *'I mean I'm from Killarney and there's just not many for pregnancy [classes], like I like pregnancy yoga and stuff like that, I would like to try those things but there's nothing really in the town' (PW08)* Resources: *'I have always been looking out for them but with working full time it's hard, these groups are like usually mid-morning like 11 on a Tuesday morning and they are never on a 7 on a Thursday evening so really I wouldn't be able to go to them' (PW13)* Built environment: *'I live in quite a hilly area so. It's hard, obviously with the buggy and everything, It would be harder. If I want to go on the flat, you know have to get in the car then' (PW07)* Built environment: *'I live in the country side on a busy road so it hard to go walking there and I don't drive, its only my husband that drives and when he's at work I can't really go anywhere' (PW08)* Weather: '*If you have things ready for the weekend and doing PA and stuff it depends and weather and stuff like' (PW01)* Weather: *'Summer time the weather is OK and we could probably go to the park every day but if it*

				start raining you are stuck in the house for a couple of weeks so it's not good' (PW03)
Social opportunity – Opportunity afforded by interpersonal influences, social cues and cultural norms that influence the way we think	**Social influences** (Process that can change thoughts feelings or behaviours – social pressure, social norms, group conformity, social comparisons, social support, group identity, modelling	- Acknowledged support from family members, partner and friends - Interaction with other pregnant women [PA classes] was mentioned	Husband: *'Actually, that's my problem because I hate it [PA], my husband is always pushing me to go for a walk' (PW22)* Husband: *'My husband and I would be quiet active; we have a dog so me and my husband would go the beach at the weekend' (PW13)* Husband: *'Probably my husband would be the one obviously, that I speak to more often about it. He would say, "Let's try and get out for a walk tomorrow." that kind of encouragement' (PW21)* Husband: *'Especially my husband, he would drag me out for a walk, you need to move cause really when you get big and walk is really important' (PW03)* Family: *'We [family] do try to do something physical like walking, walking is the main thing, trying to go to the park, trying to run around rather than doing something indoors' (PW01)* Family: *'I do try to get my son involved in going swimming' (PW01)* Classes: *'I think a lot of people would take that up [pregnancy PA classes]. Even if it was just something simple like in a community centre like, simple exercises just to help, I would definitely go' (PW18)*	Family: *'Put your feet up' that's what I get especially over the last four weeks, from my mother in law' (PW16)* Family: *'Walking with the kids is totally different on my own [laughter] it's less stressful, not with the 11 year old now because she kind of does her own thing. The 3 year old, he doesn't walk; he runs. So you're constantly calling him back. And you're watching then if you're out on the road, like ya know if you're on the footpath you're constantly watching in case he goes on the road. So I try and go on my own if I can. But if not then I bring him with me like' (PW10)*

			Classes: *'I think a good idea would be, like I don't live in cork city, I live in Clonakilty, I think if there was a pregnancy group that met once a week, where we could talk about diet and exercise and how we are doing and feeling, like a support group' (PW13)* Classes: *'I'd say it would be that extra motivation [PA classes]. Get out and make friends and talk more, and enjoy the activity more' (PW04)* Classes: *'I would love that, ya cause at least you know you doing it right and you won't strain yourself and in case you get an injury [PA classes]' (PW15)* Classes: *'I even find those parent and toddler groups, they are great. A way of kids mixing with other children, mothers to talk and for women living outside the city and I think that would be a great stepping stone, like let's have a walking day' (PW01)* Friend: *'So when I was going to the gym, my friend was going so we pushed each other so I think if I going with someone who sticks to it then I would' (PW08)*	
Reflective Motivation – Reflective process involving plans (self-conscious	**Professional /social role and identity (set of behaviours and displayed personal qualities in a**	- The 'individual'	- Every pregnancy is different / depends on the person (social role identify)	

intentions) and evaluations (beliefs about what is good and bad)	**social or work setting)**			
	Belief about capability (acceptance of the truth, reality or validity about an ability, talent)	- Using pregnancy as an 'excuse' - Concern for health of the baby - Feeling responsible - Difficulty breaking habits/mind-set	Baby: '*I just have to…keep going and just be as healthy as I can be now, I mean it's all for the baby' (PW13)* Baby: *'I think it's every women will make the choice herself [healthy lifestyle] and what she's feels herself, what she needs for her body and the baby' (PW12)* Baby: *'when I came out of my doctor I knew I was going to do something that was going to help me and the baby and that my actions would make us healthier together ya know. (PW18)* Responsibility: *'I think when a woman, no matter when pregnant or expecting pregnancy when you carry someone inside you, you should have the responsibility to provide as best as you can for the baby' (PW03)* Responsibility: *'…very woman is different and every woman will take on board information differently. I think it is very important when you're pregnant, you need to just take responsibility like, and you do. (PW19)*	Mind-set: *'I don't know if it would have mattered, I can't tell, because I just get my days where I don't care and I should care I know. I'm just not in the humour. (PW02)* Mind-set: *'If I was motivating myself more I suppose [PA] yeah that would encourage me, it's just hard to get into that mind-set' (PW09)* Mind-set: *'The first week you are eager to go [Gym], oh I'm going to gym but the following weeks maybe once in a week, in a month maybe once in a month before you know it you forgot all about it' (PW30)* Habit: *'No I would have to have been doing it from the start [PA]. I wouldn't have picked it up half way through. I definitely would have had to have started at the beginning. I mean I told myself at the start, I actually wouldn't mind doing that [PA] and keeping it up but I just didn't and then I just stopped and sat and eat….it's hard to break that habit especially when you are pregnant as you do use it as an excuse' (PW02)*
	Intentions (A conscious decision to perform a behaviour – stability of	- Post-partum intentions (planning weight loss/healthy lifestyle)	Intentions*: 'I have it planned out in my head that, I do evenings and I finish at half 1 and if I went to the gym for a half hrs. . I know it's night time but I will try and I would be happy with that' (PW02)* Intentions*: 'I know I am not having any more and I*	

	intentions, stages of change)		*tell myself afterwards I'll get back into it and I will stop all the rubbish eating and I know I will do it' (PW02)* Intentions*: 'So I said right when this baby now is done…after I have recovered I'm going back to my classes' PW05*	
Automatic Motivation – automatic processes involving emotional reactions, desires(wants and needs) impulses inhibitions drive states and reflex responses	**Emotion** (a complex reactions (experiential, behavioural, physiological- fear, anxiety, affect, stress, depression, positive and negative effect, burn out)	- Feelings of worry, concern and guilt during pregnancy - Fear for baby based on previous pregnancy outcome/ miscarriage	Guilt: '*…if I could get away with it [no PA], if I could I would definitely but I know I would feel pure guilty. I know I would have then looking at me and I would feel fierce guilty' (PW18)* Worry: *'I think no matter how babies or pregnancies the woman has for every single one they still worry, worried,, they want to make sure the baby is health' (PW03)* Worry: '*…the first time round I could go for walks, I was taking care of my health and ya know, you kind of that bit worried the first time round, you make sure you are doing the best for the baby and yourself' (PW01)*	Fear: '*...from the moment I knew I was pregnant it has been terrifying for me. Because like I've, after having 3 miscarriages in 2 years it's not a nice thing to experience, I mean you're constantly waiting to see that heartbeat..' (PW05)*

behavioural regulation and goals were merged due to the overlapping construct of 'action planning'
PA, Physical activity; HCP, Health care professional

Figure 12: Pregnant women research brief

Research Brief

June 2017

Physical activity for overweight and obese pregnant women

Evidence from Cork University Maternity Hospital

Although the benefits of physical activity during pregnancy are well documented in the literature, women's activity levels often reduce or cease during pregnancy. Moreover, adherence to physical activity guidelines is particularly low for pregnant women with a body mass index >25kg/m². Research suggests incorporating theory in intervention development helps reduce the decline of physical activity throughout pregnancy.

Benefits of physical activity during pregnancy (1, 2)

- Increase in functional mobility
- Reduction in nausea and vomiting
- Prevent pregnancy complications
- Limit pregnancy weight gain
- Decrease the risk of gestational diabetes

Therefore, this research employed recent tools in behavioural science; the Theoretical Domains Framework (TDF) and COM-B model (capability, opportunity, motivation and behaviour) (3, 4) to better understand the factors enabling or inhibiting physical activity behaviours for overweight and obese pregnant women.

Methods of the study

- Semi-structured interviews were conducted with a purposive sample of 30 overweight and obese women at different stages of pregnancy attending a public antenatal clinic at Cork University Maternity Hospital.
- Interviews were recorded and transcribed into NVivo V.10 software.
- The framework approach was employed and emerging themes were then mapped to the Theoretical Domains Framework (TDF) and COM-B model (capability, opportunity, motivation and behaviour).

Barriers to physical activity for overweight and obese pregnant women

Capability

Pregnancy related symptoms were a reason for participants to undertake little or no physical activity. Barriers related to physical health including muscle pain, pelvic or lower back pain, swelling and other conditions. Another barrier was that of feeling too tired to engage in physical activity; finding it hard to move, a lack of energy and being physically drained during pregnancy.

> *"It's harder to move faster now that I am pregnant. Like sometimes I have energy and some days I don't... It's difficult, like you feel like you want to do stuff but you can't, your body is just tired and drained physically"*

Women received little information around appropriate types of exercise in pregnancy, describing the information as *'limited'*, *'quick'*, *'automatic'*, *'like a checklist'*.

Opportunity

Other family members were seen as barriers to physical activity.

'Put your feet up' that's what I get especially over the last four weeks, from my mother in law'

Motivation

A fear based on previous pregnancy outcomes was highlighted with women afraid to do any exercise due to previous miscarriage experiences.

"...from the moment I knew I was pregnant it has been terrifying for me. Because like I'm after having 3 miscarriages in 2 years"

This research brief is designed to provide information for health care professionals and policy makers about the enablers and barriers to physical activity in overweight and obese pregnant women.

Research Brief

June 2017

Enablers to physical activity for overweight and obese pregnant women

Capability

Being physically fit before pregnancy was identified as a potential enabler.

> ***'I don't know I think it depends on everyone's circumstances. Like a lot of women would be fit before they got pregnant and they would keep up their walking or running'***

Women suggested that action planning; goal setting and self-monitoring would be an enabler to physical activity. 'Pedometers' or 'step counts' might help in terms of motivation and to monitor current levels of physical activity.

> ***'If there was definitely some sort of measurement like a pedometer or something like that, just something that would flag where you are at and what your targets should be'***

Opportunity

Women also expressed an interest in pregnancy exercise classes giving mothers a chance to ***'talk'*** and compared these classes to a ***'support group'***.

Motivation

Pregnancy was viewed as a time of change particularly for the benefit of the baby ***'I just have to…be as healthy as I can be now, I mean it's all for the baby'***.

Others reported being motivated when talking about after pregnancy and their implicit intentions to change.

> ***'I have it planned out in my head', 'I know I am not having any more and I tell myself afterwards I'll get back into it'***

Types of physical activity behaviours identified

- Walking
- Swimming
- Aqua aerobics
- Pregnancy physical activity classes
- Pilates and yoga
- Housework

Recommendations

- ➢ Being active can reduce pregnancy symptoms. This may be a useful motivational strategy to encourage women to be active early on.
- ➢ Taking a holistic approach to care, taking into consideration the women's social support network (family/friends) and to include their partners in group pregnancy sessions.
- ➢ Future interventions should include some component of self-monitoring (pedometers) in order to improve physical activity levels.
- ➢ Use results from this study to inform the development of a physical activity intervention for pregnant women.

Conclusion

This research provides an overview of the behavioural factors enabling or inhibiting physical activity amongst pregnant women with overweight and obesity. Using the TDF and COM-B model is a theoretical starting point for understanding physical activity behaviour and to make a 'behavioural diagnosis' of what needs to change to alter behaviour.

Authors

*Caragh Flannery, Sheena McHugh, Ann E Anaba, Emma Clifford, Mairead O'Riordan, Louise Kenny, Fionnuala M McAuliffe, Patricia M Kearney, Molly Byrne

*Corresponding author

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'Supporting excellent research that improves people's health, patient care and health service delivery'

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Exploring obstetricians, midwives and general practitioners approach to weight management in pregnant women with a BMI ≥25: a qualitative study (Study 3)

Health Care Professional Information Sheet

Experiences of lifestyle management and support during pregnancy **Participant Information Sheet**

Principle Investigators: Prof. Patricia Kearney, Dr Sheena Mc Hugh
Study team: Emma Clifford, Caragh Flannery
Address: Department of Epidemiology & Public Health, 4th Floor
Western Gateway, University College Cork.
Email: s.mchugh@ucc.ie , cflannery@ucc.ie

Introduction
You are invited to take part in this study to explore your experiences of providing lifestyle advice and counselling during pregnancy. It is completely up to you to decide whether you wish to participate in this study. This leaflet gives detailed information about the research study, which will be discussed with you. Once you understand the study, you will be asked to sign this form if you wish to participate.

About the study
Antenatal care provides a unique opportunity for screening, providing lifestyle advice and encouraging behaviour change. There is a lack of research examining health care professionals' experiences and concerns about lifestyle management and obesity during pregnancy. The purpose of this study is to understand current practice around lifestyle management and advice during pregnancy and the challenges to behaviour change from the health professional perspective. We would like to know what you think are the best and most feasible ways of supporting behaviour change among pregnant women at risk of gestational diabetes. The study is funded by the Health Research Board in Ireland. We are inviting you to take part in an interview which will last between 30 and 40 minutes. During this time you will be asked what you think about different ways of supporting behaviour change during pregnancy among pregnant women at risk of gestational diabetes and the challenges within the current health system. You can select a suitable time, date and location for the interview and one of our team will travel to meet you. If it is agreeable with you, the interview will be recorded by the researcher to assist with recording the information.

Benefits & Risks
We hope that the results of this study will be used to develop more effective interventions and inform the resources and services available to women and health care professionals during pregnancy. The interview will be an opportunity for you to share your experiences and provide feedback on the best ways to support women in relation to lifestyle management during pregnancy. We do not anticipate any risks.

Participation

Taking part in this study is voluntary. If you agree to take part you are free to withdraw from the study at any time without having to give a reason.

Confidentiality

No material which could personally identify you will be used in any reports on this study.

Any identifiable information will be removed from the interview transcripts so all data will be anonymised. A unique study number will be assigned to tapes and transcripts to ensure the confidentiality of any records we keep. Information will be stored securely on password protected computers in the Department of Epidemiology & Public Health in University College Cork. Only members of the research team named on form will have access to the data. In accordance with the Data Protection Act the interview transcripts will be kept for 7 years after which time they will be deleted.

Results

The study results will be published in medical journals and will be available from the research team.

General Information

More information about the study can be obtained from any member of the research team. You do not have to answer all the questions asked during the interview and you may stop the interview at any time.

Statement of Approval

This study has received ethical approval from the Cork University Hospitals Research Ethics Committee**.**

Health Care Professional Consent Form

Experiences of lifestyle management and support during pregnancy **Consent Form**

Principle Investigators: Prof. Patricia Kearney, Dr Sheena Mc Hugh
Study team: Emma Clifford, Caragh Flannery
Address: Department of Epidemiology & Public Health, 4th Floor Western Gateway, University College Cork.**Email:** s.mchugh@ucc.ie , cflannery@ucc.ie

- I confirm that the research project and the interview have been fully explained to me.

- I have read and understood the Information Sheet dated xx/xx/xx and have had an opportunity to ask questions about the project, to which I have had satisfactory answers.

- I am aware that participation is ***voluntary*** and that I may withdraw my consent at any time without having to give a reason.

- I am aware that my decision not to participate or to withdraw will not have any personal consequences for me.

- Confidentiality of records concerning my involvement in this project will be maintained in an appropriate manner. When required by law, the records of this research may be reviewed by government agencies and sponsors of the research.

- I understand that the sponsors and investigators have such insurance as is required by law in the event of injury resulting from this research.

- I have received a copy of this consent form and the participant information sheet for my records.

I, the undersigned, hereby consent to being a participant in the above described study conducted at the University College Cork. I understand that if I have any questions concerning this research, I can contact the researcher listed above. If I have further queries concerning my rights in connection with the research, I can contact the Clinical Research Ethics Committee of the Cork Teaching Hospitals, Lancaster Hall, 6 Little Hanover Street, Cork. After reading the entire consent form, if you have no further questions about giving consent, please sign where indicated.

....	....	....
Participant Signature	Name in Block Capitals	Date
....	....	....
Researcher Signature	Name in Block Capitals	Date

Table 24: Health care professional's topic guide

	Questions	Prompts
Intro	Tell me a bit about what you do here in CUMH	Types of pregnant women Stage of pregnancy (booking visit, delivery)
Usual Care	When you see an OB woman for the 1st time during pregnancy, what usually happens?	What does the assessment/visit involve? Do you weigh them? What do you talk about? How do you think that information is usually received? What issues does the woman usually raise? Topics covered: diet, exercise, nausea, cravings
	Can you tell me a bit about the last women you saw?	What stage of pregnancy? When was this? Describe the mother… What did you talk about? What issues did she raise? Topics: diet, PA, nausea, cravings…
	Do you discuss the woman's weight specifically?	Tell me about that… - Appropriate weight gain - How do you judge (guidelines) - Do you know what advice to give?
	Having the conversation	How do you feel talking about weight and obesity? How is it received? (upset, shock, embarrassment) How could this conversation be made easier? (for you/the woman)
	And what about PA, would that come up?	- Women previously exercising? - Types of PA?
	How are these issues followed up during pregnancy?	If a woman is gaining EGW, what would you do?
	To what extent do resources influence your visit with an OB pregnant woman?	- Time available - Access to equipment (weighing scales) - Ability to refer to dietician - Patients co-operation
Behaviour Change	Can you think of times where women have made positive life style changes during pregnancy? And those who haven't made any changes, what were the barriers?	Tell me about that…. Motivations, Supports, Outcome Any targeted support available? - Dietetic services, exercise programmes, weight management programme. - Women's perceptions of PA (benefits)
	What do you think would help these women to change their behaviour during pregnancy?	Have you seen technology being used to support BC? - What kind, features, - Did someone recommend it? - What information was it providing to women?

	What about mobile phone apps, text message/phone, web based information forums, pedometer? Would these support mechanisms be useful? - If it provided you with information as well
Any other comments or suggestions on how behaviour change could be supported during pregnancy?	- Individual meetings - Group peer led sessions

CUMH, Cork University Maternity Hospital; OB, overweight and obese; PA, Physical activity; HCP, Health care professional; EGW, Excessive gestational weight; BC, Behaviour change

Table 25: Drivers and approach to weight management for pregnant women with overweight and obesity

Themes	Quotes
The "softly-softly" approach to weight management - Population level - Stigma - Conversation - Women reactions	*'I think the public health message is probably just a little bit too softly softly' (Obstetrician, 07)* *'Yes and there is a certain element of that and it's, "What the hell I'm fat anyway, what's the point, let's keep going and I'll sort it out afterwards.' (GP 01)* *'Look I'm pregnant so, let's just let it all hang out. I can eat what I want and I'll sort it out after I've had the baby." and I don't think they realise that being obese in their pregnancy is going to have implications for their child as well as themselves' (GP 02)* *'I found that a lot of women have an excuse if they do know that their BMI is high they say, "Oh, I know, but I'm quite big boned or I'm like this my whole life."' (Midwife 02)* *'"I'm pointing this out because it puts you at risk of these things." but very often the shutters come down and they don't want to engage in any sort of conversation about it.' (Obstetrician 03)* *'…their peer group will have gone through pregnancy obese and have a healthy baby and they will look at the people and think they didn't have a problem why do I have to do something about it' (GP 05)* *'we're just a little bit too softly-softly with obesity and whether we should be actually saying, "If you embark on pregnancy and you are obese-." and we rowed back from using the word fat because it's thought to be derogatory or insulting so we use euphemisms, "You're got too much adiposity." we talk a lot about BMIs because it's numerical, but I think the public health message could be a little bit more black and white..' (Obstetrician07)*
Broaching the subject of weight - Confidence - Detached approaches	*'I must admit I have been wary about raising the subject of weight and I would be conscious of the fact that for a lot of women they themselves are conscious of their weight and I would prefer not to be adding to their distress' (GP 01)* *'I would feel uncomfortable bringing up their weight with them (GP02)* *'Usually, if it's a routine clinic then I might feel a bit awkward bringing it [weight] up' (SHO 05).*

	'And I guess when I meet younger midwives, they say they don't like to talk to people about their weight, the more you do something the easier It comes Ya know' (Midwife 01)
"Doing what you can with what you have" to support the management of overweight and obesity - Adapting the evidence - Limited services - Weighting practices	*'The answer is no, I don't have any specific written guidelines that I'd be aware of and there'd be no protocols I'd follow. I'd just be conscious of the overall weight gain and just ensuring that weight gain is not excessive' (GP 01)* *'I always say eight kilos is the average. I can't give you a reference for that right now, but I could probably find one' (Obstetrician 03)* *There's a lot of literature out there, particularly from the US about appropriate weight gains…..and all the rest of it, but actually, the evidence, it's very hard to advise….. because the evidence supporting that is not spectacular' (Obstetrician 09)* *'I know that sounds a bit silly, but at least if there is a difficulty, something like diabetes, I can explain to them getting the weight down and watching your diet could help with this and I try to explain that side of things to them, but routinely it probably is a bit the elephant in the room that's not brought up' (SHO, O5)* *'..I think in many ways, by the time women turn up to us with an increased BMI, there is very little we can do'. (Obstetrician 09)* *'We have a dietician for patients who are diagnosed with diabetes, but it would be great if I could refer patients to a dietician about other health issues like obesity or if they just needed advice on nutrition' (GP 07).* *'…So even if you explore it with them and you say, "I'm going to refer you to a dietician." and they don't get an appointment for two months, they've lost that, they're then 34 weeks pregnant they're exhausted…..' (GP 02)* *'..we're stretched far too thinly and we don't have adequate supportive services in terms of occupational therapy and dietetics. Even the diabetic service here is really poorly funded and poorly staffed' (Obstetrician 07)* *'Because there is a lack of resources in general practice I mean that is definitely there right now in the community, we don't have the resources, we're very, very stretched and all I can do is mark her as a risk factor and let them know in the hospital' (GP 04)* *'They're not weighed anymore because I haven't seen the data myself, but there is data to show that there's no benefit in it.*

	There is data somewhere that says it doesn't improve outcomes' (Obstetrician 06) *'it was stopped being done as routine because it wasn't correlating with health outcomes. That's my understanding of it, but I certainly would be interested to see if there are new guidelines about it. So if it is significant, I think it should be included in the chart' (GP 03)* *'I think the fact that there's no place to record weight on the antenatal charts. Not that you want women-, I don't know why they haven't it in, somebody else said that the obstetricians don't worry about weight in pregnancy, but I don't know, I just think it's a bit unusual.' (GP 06)* *'I suppose not really, not for tackling, like education and actual teaching ladies about what they can do, probably not from that side of things. I think we identify the risk well enough, but whether we can tackle it is another story and I don't think we have really much resource for that' (SHO 05)*
Shifting the focus to the management of obstetric complications - Complications	*'Yes I do. I feel that this is so important that we can't not talk about it and I say to women-, if I'm getting that kind of anger thing I say, "Look, when you smoke I tell you to stop smoking, obesity is just like that. It's a risk factor, it's bad for you it's bad for your baby' (Obstetrician 03)*
Unclear roles and responsibilities for lifestyle advice - Responsibility - Communication	*'so Ideally the GP knows that woman before she got pregnant knows maybe her family situation, she might have another child at home and maybe he/she has seen that child and maybe that child Is overweight so he/she can look at a better family picture……… I think there GP should be one that should keep an eye on it, he is the continuous person that's with them…….the GP can give a very continuous care programme to the woman..'. (Midwife 01)* *'In terms of the medical side, I think the GPs have to do a little bit because they know the patient better and I think-, I'm not scared of saying that they're obese and they have to lose weight, but it's the time and the place. So usually by the time they get to me it's too late and it's not going to change anything (Midwife 10)* *'..I would refer a woman for antenatal care to the CUMH. Send up the letter, bloods are done and apart from the folder they get their chart, we don't know what's going on….They don't write to us to say we've received-, before they would right and thank you for your letter and partaking in combined antenatal care. You get very little really; you just get the discharge summary once the baby is born. I know they're very busy up there too.' (GP 07)*

10 APPENDIX C: SUPPLEMENTARY MATERIAL STUDY 4

Physical activity interventions for overweight and obesity during pregnancy: A systematic review of the effectiveness and content of behaviour change interventions (Study 4)

PROSPERO
International prospective register of systematic reviews

NHS National Institute for Health Research

Physical activity interventions for overweight and obesity during pregnancy: a systematic review of behaviour change interventions

Caragh Flannery, Molly Byrne, Ellinor Olander, Fionnuala McAuliffe, Patricia Kearney

Citation

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Review question

For pregnant women with overweight and obesity, are behaviour change interventions effective in increasing physical activity levels?
1) To describe how physical activity interventions are delivered (format, technology vs face to face, setting, intensity and duration).
2) To characterise using a published taxonomy the behaviour change techniques used in physical activity interventions.
3) To identify which behaviour change techniques are more likely to be effective in improving physical activity levels in overweight and obese pregnant women.

Searches

The following databases will be searched (from inception): MEDLINE, EMBASE, PsycINFO, CINAHL, Cochrane Library, PEDro, SPORTDiscus and PubMed. Different combinations of phrases/mesh headings will be used for each component of PICO using OR, and combined using AND:
- Population: maternal, pregnancy, pregnant woman, expectant mothers.
- Intervention: lifestyle, lifestyle modification, health promotion, behaviour change, physical activity, exercise, fitness, activities of daily living, human activities, group exercise, randomised controlled trial, intervention trials and clinical trials.
- Comparator: standard care.
- Outcomes: physical activity, gestational weight gain and gestational diabetes.

The search strategy will be initially developed in PUBMED and appropriately tailored for the different databases.
Other sources:
Forward and backward citation searches will be conducted on all eligible articles following screening.

Types of study to be included

Studies investigating the effectiveness of behavioural interventions designed to increase physical activity levels will be included in this review. Studies will be included if physical activity is objectively or subjectively measured. Randomised control trials, non-randomised control trials, quasi RCTs, and quasi-experimental studies will be included. No limits on the methods in which the intervention was administered (e.g. via telephone, internet, in person) will be set.

Condition or domain being studied

In this era of obesity, excessive weight gain and obesity during pregnancy is an increasing public health concern. It is associated with a number of adverse maternal and neonatal outcomes including risk of gestational diabetes, pre-eclampsia, caesarean section, instrumental delivery and preterm delivery (Campbell et al., 2011). Women who are obese are not only at risk of pregnancy complications but also weight retention in the longer term (Hinton and Olson, 2001, Gore et al., 2003).
Physical activity has been identified as a modifiable lifestyle factor that could help prevent pregnancy complications, help with weight management and reduce the risk of gestational diabetes for obese woman

(Gynecologists, Update Dec 2015). Previous research has found that physically active pregnant women have reported improved health as well as an increase in functional ability and a reduction in nausea, fatigue and stress (Artal and O'Toole, 2003, (RCOG), 2006, Nascimento et al., 2012). Current national and international guidelines (ACOG, 2003 and RCOG, 2006) recommend 30 minutes of daily moderate intensity physical activity for pregnant women. However, despite this, many pregnant women reduce their activity levels in pregnancy. A review which updated the latest evidence concerning exercise during pregnancy found that in the United States only 15.8% of women engaged in exercise during pregnancy at the recommended level. Similarly low levels of physical activity levels have been reported in an Irish cohort of pregnant woman with only 21.5% of women meeting the current recommendations (Nascimento et al., 2012, Evenson et al., 2004, Walsh et al., 2011).
There are many interventions aimed at promoting lifestyle changes throughout pregnancy which are usually multidimensional incorporating a combination of diet and physical activity (Williams and French, 2011). Reviews of lifestyle interventions are varied and results to date are conflicting. Moreover, the underlying behaviour change techniques employed are often ignored. Without these underlying theories it is difficult for researchers and clinicians to understand the context for the success or failure of the intervention and the key transferable intervention components (Asbee et al., 2009).
Behavioural modification is complex and involves identifying effective and efficient techniques to bring about change. According to a review by Currie et al (2013) which evaluated the content of physical activity interventions for pregnancy, lifestyle interventions are most effective when behaviour change techniques are employed and delivered face to face (Currie et al., 2013). However there is uncertainty around which underlying behaviour change techniques are most effective. Collins et al put forward two components that need to be explored in order to identify effective interventions. These are; intervention programme (employed behaviour change technique) and intervention delivery (intervention provider, format, setting, recipient, intensity, duration and fidelity of the intervention) (Collins et al., 2005). Previous systematic reviews in this area (Currie et al., 2013, Skouteris et al., 2014) have assessed intervention effectiveness but have not examined the intervention programme itself. Therefore the aim of this systematic review is to evaluate the effectiveness of physical activity interventions for overweight and obese pregnant women with a specific emphasis on the intervention programme, i.e. the behaviour change techniques employed to elicit behaviour change.

Participants/population

Overweight and obese pregnant women with a pre-pregnancy or early pregnancy body mass index (BMI >=25).
Single births.

Intervention(s), exposure(s)

Studies will be included in which a physical activity intervention was delivered, aimed at maintaining or increasing physical activity levels. Interventions may include additional components, such as targeting dietary behaviour. All interventions must target overweight and obese pregnant women (BMI >=25), have at least one component focusing explicitly on physical activity and include an identifiable behaviour change technique.

Comparator(s)/control

Control groups will be defined as having usual/standard antenatal care.

Context

Included studies will be those where participants have been recruited to a physical activity intervention that is conducted either in a health care setting, community setting, online or individual's home.
All studies regardless of language will be included where possible.
Exclusion:studies published in the grey literature(non-peer reviewed or without scientific credibility).

Primary outcome(s)

Change in physical activity levels subjectively (e.g., self-report) or objectively measured (e.g., step count) at baseline, pre and post intervention.

Secondary outcome(s)
Gestational weight gain and gestational diabetes where available.

Data extraction (selection and coding)
The titles and abstracts of articles retrieved from the search strategy will be screened independently by two reviewers. Full text of relevant articles will be evaluated. Where there is uncertainty about eligibility a third reviewer will be consulted. Discrepancies will be discussed and resolved by consensus.
Data will be extracted using a pre-designed data extraction form which will include: name of first author, year of publication, study design, participant characteristics, details of the intervention (sample size, type; physical activity, or combination of physical activity and diet, format, technology vs. face to face, setting, intensity and duration) and behaviour change techniques included in the intervention. Physical activity measures for baseline, pre and post intervention will be recorded. Behaviour change techniques will be extracted by two researchers using Michie's et al Behaviour Change Technique Taxonomy (v1) (Michie et al., 2013). Ratings will be made independently for techniques targeting physical activity change based on the published intervention descriptions. Data extracted will be stored on an Excel database for analysis in Stata and RevMan.

Risk of bias (quality) assessment
The Cochrane Collaboration's tool for assessing risk of bias will be used to appraise the methodological quality of the studies (sequence generation, allocation concealment, blinding of participants, personnel and outcome assessors, incomplete outcome data, selective outcome reporting, other sources of bias)(Green, 2011). Two researchers will independently assess the quality for each included study. A third member of the team will be available if consensus is not reached.

Strategy for data synthesis
A summary of the characteristics of the study populations, designs, intervention, comparators, outcomes and results will be provided in summary tables for all studies. A meta-analysis will be conducted for studies with comparable analyses to establish overall outcome effects using the statistical guidelines provided in the Cochrane Handbook for Systematic Reviews of Interventions (Green, 2011). For all effect sizes 95% confidence intervals will be derived using Cochrane Review Manager Software (RevMan 2010). If data is not sufficiently homogeneous, a narrative synthesis will be used to summarise and explain the individual studies. Behaviour change techniques will be coded using the behaviour change technique taxonomy (Michie et al)(Michie et al., 2013). Regression analysis will be used to assess the effects of modes of intervention delivery, number of behaviour change techniques and individual behaviour change techniques on physical activity using Stata.

Analysis of subgroups or subsets
Subgroup analysis will be conducted where appropriate (e.g. to examine the different types of physical activity interventions, methods of behaviour change and methods of intervention delivery).

Contact details for further information
Ms Flannery
cflannery@ucc.ie

Organisational affiliation of the review
Health Behaviour Change Research Group, National University of Ireland, Galway
http://www.nuigalway.ie/colleges-and-schools/arts-social-sciences-and-celtic-studies/psychology/research/research-themes/health-wellbeing/health-psychology/

Review team members and their organisational affiliations
Ms Caragh Flannery. Health Behaviour Change Research Group, School of Psychology, NUI Galway
Dr Molly Byrne. Health Behaviour Change Research Group, School of Psychology, NUI Galway
Dr Ellinor Olander. Midwifery and Radiography, City University London

Professor Fionnuala McAuliffe. School of Medicine, University College Dublin
Professor Patricia Kearney. Department of Epidemiology and Public Health, University College Cork

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Conflicts of interest
None known

Language
English

Country
Ireland

Stage of review
Review_Ongoing

Subject index terms status
Subject indexing assigned by CRD

Subject index terms
Behavior Therapy; Female; Humans; Motor Activity; Obesity; Pregnancy

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Revision note for this version
As this systematic review focuses on an overweight and obese pregnant population (BMI>=25), the authors decided to focus only on interventions that target this population. This decision was made because studies that include pregnant women irrespective of BMI did not analyse BMI categories separately. Overweight and obese pregnant women are likely to respond to interventions differently than those in a normal BMI category. The review stage has been updated.

Details of any existing review of the same topic by the same authors

Stage of review at time of this submission

Stage	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	Yes
Data extraction	Yes	No
Risk of bias (quality) assessment	No	No
Data analysis	No	No

Revision note

As this systematic review focuses on an overweight and obese pregnant population (BMI>=25), the authors decided to focus only on interventions that target this population. This decision was made because studies that include pregnant women irrespective of BMI did not analyse BMI categories separately. Overweight and obese pregnant women are likely to respond to interventions differently than those in a normal BMI category. The review stage has been updated.

Versions

21 January 2016
11 July 2016
10 January 2017
14 June 2017

Table 26: Methodological quality rating

Reference	Sequence generation	Concealed allocation	Outcome assessment	Retention rate	Missing data handling	Other bias	Overall risk of bias	Rational/ notes
Callaway et al 2015	A	U	U	70%	U	U	Unclear	Random number allocation technique conducted by third party at another location; Unclear information across most areas
Dodd et al 2014	A	A	U	86%	A	U	Low	Telephone central randomisation service which utilises a computer generated schedule with balanced variable blocks; Intention to treat basis; Women were aware of the treatment allocation; Generally well conducted RCT with PA measures; Recall bias
Hawkins et al 2015	N	U	U	77%	A	U	Unclear	Randomised by the health educators; Intention to treat Unclear information across most areas; Small sample size; Recall bias
Kai Ling Kong et al 2014	A	A	A	88*	U	U	Low	Assigned to intervention/control using a computer based random sample generator; No detail on missing data; Generally well documented; small sample size and high variance
Oostdam et al 2012	A	A	A	40%	A	U	High	Computerised random number generator; After baseline – women were informed about their group allocation; Research and research staff will not be blinded but all independent examiners will be unaware of group allocation; Intention to treat; High dropout rate

Table 26: Methodological quality rating (continued)

Reference	Sequence generation	Concealed allocation	Outcome assessment	Retention rate	Missing data handling	Other bias	Overall risk of bias	Rational/ notes
Poston et al 2015	A	A	U	90%	A	U	Low	Computer generated randomisation procedure; Intention to treat; Missing at random assumption; Self-report
Renualt et al 2014	A	U	U	91%	U	U	Unclear	Randomised by a dietician – web allocation by an independent organisation; Intention to treat approach; Unclear information across most areas; no data from control group after the intervention; homogeneity – lowers external validity
Szmeja et al 2014	A	U	U	99%	U	U	Unclear	Telephone central randomisation service – computer generated schedule; Intention to treat; Unclear information across most areas
Vinter et al 2011	A	U	U	20%	U	A	High	Randomisation computer generated numbers in closed envelopes; Selection Bias
Santos et al 2005	A	A	U	78%	U	N	High	Randomised using a block sequence generator from a random number table by a statistician; Un-blinded program of supervised PA; Intention to treat; Attrition during the follow up was relatively high
Ong et al 2009	N	U	U	U	U	U	Unclear	Participants were randomly allocated – no detail; Unclear information across most areas

Table 26: Methodological quality rating (continued)

Reference	Sequence generation	Concealed allocation	Outcome assessment	Retention rate	Missing data handling	Other bias	Overall risk of bias	Rational/ notes
Guelinckx et al 2010	N	U	U	62%	U	N	Unclear	Randomly allocated – no detail; Recall bias; Unclear information across most areas
Koivusalo et al 2016	A	U	U	91%	U	U	Unclear	Randomly permuted process – the randomisation process was performed by a study nurse and by dispensing the next sequentially numbered subject code and opening the corresponding code envelope; Unclear information across most areas
Garnaes et al 2016	A	A	A	81%	A	A	Low	Randomly allocated using a computer random number generator; Statistician was blinded; Weight measurement and blood's completed by blinded personnel; All other assessment were done non-blinded; Intention to treat; per protocol analysis – only included the women in the exercise group who adhered to the exercise protocol; selection bias
Nascimento et al 2011	A	A	U	97%	U	A	Low	Randomised using statistical programme which generated a list of random numbers based on a uniform distribution; To ensure blinding, the sequence was randomly distributed in opaque envelopes; Analysis by treatment schedule (intention to treat); Self-report bias

Table 26: Methodological quality rating (continued)

Reference	Sequence generation	Concealed allocation	Outcome assessment	Retention rate	Missing data handling	Other bias	Overall risk of bias	Rational/ notes
Seneviratne et al 2016	A	A	U	N/A	U	U	Unclear	Two arm randomisation 1;1 allocation ratio – randomization sequence generated by biostatistician not related to the study and were used sequentially according to enrolment order; Group allocation was revealed to participants after baseline assessments recruitment coordinator did not have access to the allocations; Intention to treat; Unclear information across most areas
Bruno et al 2017	A	U	U	68%	U	U	Unclear	Computer generated random allocation sequence; Not blinded to group allocation

A: Adequate, N: Not Adequate, U: Unclear, N/A: Not applicable

Figure 13: Summary of the risk of bias

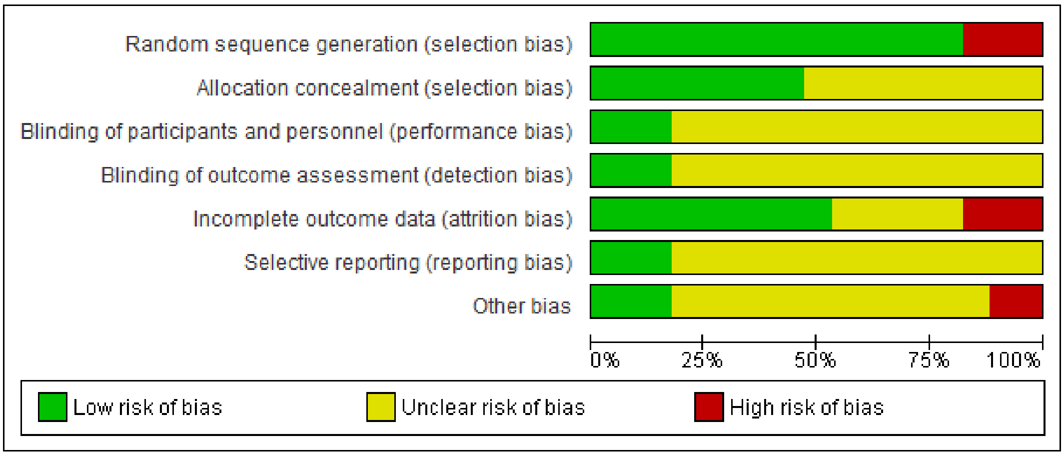

Figure 14: Funnel plot for metabolic equivalent (MET)

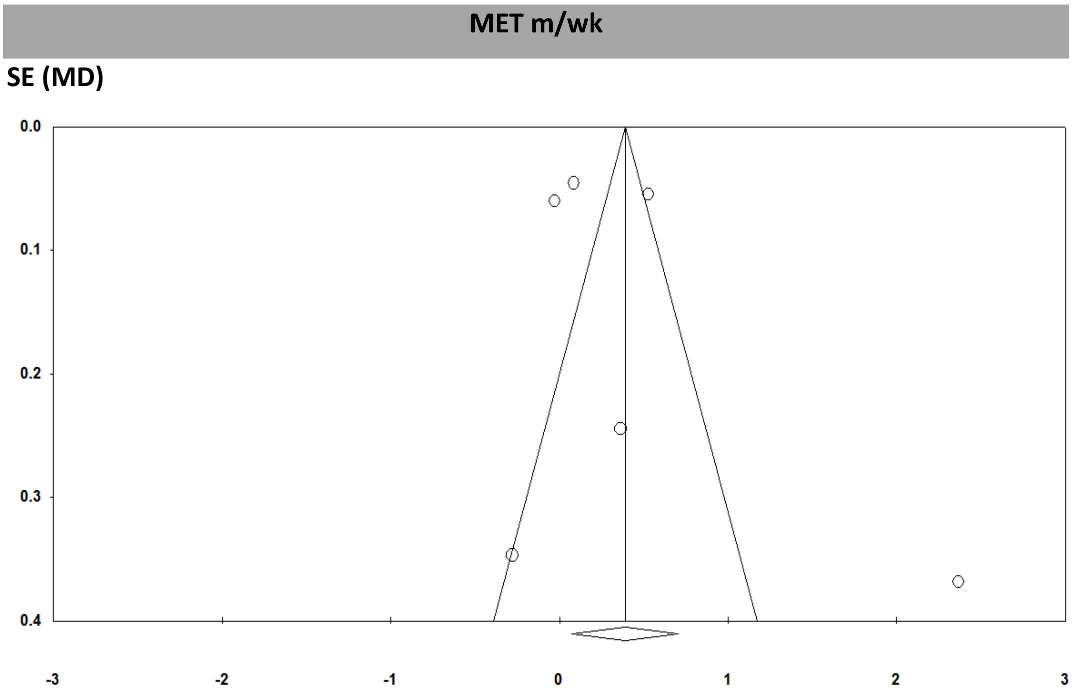

Table 27: Searches MEDLINE, PsycINFO, SPORTDiscuss, CINAHL, PEDro, Cochrane Library, EMBASE and PubMed from database inception to Jan 2018

MEDLINE

Search terms	**No of records returned**	**Updated search**
For *MEDLINE (1879 – Jan 2018)*	***June 2016***	***Jan 2018***
1. (MH “Pregnancy”)	7769819	
2. (MH “Pregnant Women”)	5638	
3. (MH “Prenatal Care”)	21932	
4. [#1 or #2 or #3]	**772027**	**18994**
5. (MH “Diabetes, Gestational”)	6955	
6. (MH “Body Weight”)	169788	
7. (MH “Weight Gain”)	25146	
8. (MH “Overweight”)	15555	
9. (MH “Obesity”)	140600	
10. (MH “Body Mass Index”)	92887	
11. [#5 or #6 or #7 or #8 or #9 or #10]	**372507**	**52107**
12. [#4 and #11]	**31215**	**1687**
13. “behav*”	1347420	
14. “behavio#r”	1042408	
15. (MH “Health Behavior”)	38336	
16. (MH “Life Style”)	46886	
17. “intervention”	398591	
18. “program#e”	90086	
19. “change”	854663	
20. [#13 or #14 or #15 or #16 or #17 or #18 or #19]	**2507332**	**282446**
21. [#12 and #20]	**5634**	**426**
22. (MH “Motor Activity”)	85382	
23. (MH “Exercise”)	76163	
24. (MH “Physical Exertion”)	53932	
25. (MH “Walking”)	23587	
26. (MH “Movement”)	63119	
27. (MH “Exercise Therapy”)	29951	
28. (MH “Leisure Activities”)	7039	
29. (MH “Physical Fitness”)	23486	
30. “physical activity”	74394	
31. [#22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30]	**362699**	**402050**
32. [#21 and #31]	**1031**	**88**
MH –Exact subject heading “…” – free text term (used when no exact subject heading was available) *truncation #wildcard		

PsycINFO

Search terms	No of records returned	Updated search
For *PsycINFO (1967 – Jan 2018)*	***June 2016***	***Jan 2018***
1. Pregnancy	35376	
2. Pregnant Women	8301	
3. Prenatal Care	2735	
4. [#1 or #2 or #3]	**37814**	**3442**
5. Diabetes, Gestational	367	
6. Body Weight	22718	
7. Weight Gain	9237	
8. Overweight	11502	
9. Obesity	30577	
10. Body Mass Index	15018	
11. [#5 or #6 or #7 or #8 or #9 or #10]	**59759**	**6036**
12. [#4 and #11]	**2143**	**306**
13. behav*	1287789	
14. behavio#r	1001457	
15. Health Behavior	51063	
16. Life Style	25001	
17. Intervention	312629	
18. Program#e	21480	
19. Change	492798	
20. [#13 or #14 or #15 or #16 or #17 or #18 or #19]	**1763830**	**132323**
21. [#12 and #20]	**1263**	**184**
22. Motor Activity	10364	
23. Exercise	62196	
24. Physical Exertion	407	
25. Walking	12640	
26. Movement	133178	
27. Exercise Therapy	1390	
28. Leisure Activities	5400	
29. Physical Fitness	5242	
30. physical activity	30421	
31. [#22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30]	**230044**	**18938**
32. [#21 and #31]	**228**	**43**
Free text terms searched *truncation #wildcard		

PEDro

Search terms	No of records returned	Updated search
For *PEDro (1999 – Jan 2018)*	***June 2016***	***Jan 2018***
1. Pregnan*		
2. Clinical trial		
3. [#1 and #2]	**399**	**56**
(Database advanced search difficult to work with so kept search strategy simple to capture everything on pregnancy and trials) *truncation		

SPORTDiscus

Search terms	No of records returned	Updated search
For *SPORTDiscus (1830 – Jan 2018)*	***June 2016***	***Jan 2018***
1. Pregnancy	8241	
2. Pregnant Women	2916	
3. Prenatal Care	450	
4. [#1 or #2 or #3]	**9005**	**510**
5. Diabetes, Gestational	228	
6. Body Weight	18175	
7. Weight Gain	3401	
8. Overweight	7189	
9. Obesity	20105	
10. Body Mass Index	12323	
11. [#5 or #6 or #7 or #8 or #9 or #10]	**44285**	**4698**
12. [#4 and #11]	**1014**	**105**
13. behav*	81237	
14. behavio#r	62291	
15. Health Behavior	10222	
16. Life Style	16086	
17. Intervention	40752	
18. Program#e	13772	
19. Change	103024	
20. [#13 or #14 or #15 or #16 or #17 or #18 or #19]	**218733**	**19173**
21. [#12 and #20]	**342**	**41**
22. Motor Activity	2400	
23. Exercise	208796	
24. Physical Exertion	604	
25. Walking	19190	
26. Movement	55312	
27. Exercise Therapy	6264	
28. Leisure Activities	4566	
29. Physical Fitness	97156	
30. physical activity	49096	
31. [#22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30]	**328358**	**21461**
32. [#21 and #31]	**135**	**22**
Free-text terms *truncation #wildcard		

CINAHL

Search terms	No of records returned	Updated search
For *CINAHL (1961 – Jan 2018)*	***June 2016***	***Jan 2018***
1. (MH "Pregnancy")	132956	
2. Pregnant Women	16790	
3. (MH "Prenatal Care")	11024	
4. [#1 or #2 or #3]	**138574**	**12262**
5. Diabetes, Gestational	4922	
6. (MH "Body Weight")	19893	
7. (MH "Weight Gain")	8117	
8. Overweight	15053	
9. (MH "Obesity")	54070	
10. (MH "Body Mass Index")	54938	
11. [#5 or #6 or #7 or #8 or #9 or #10]	**116422**	**12847**
12. [#4 and #11]	**9422**	**1294**
13. behave*	251247	
14. behavio#r	195628	
15. (MH "Health Behavior")	32472	
16. (MH "Life Style")	18243	
17. intervention	227087	
18. program#e	25825	
19. change	264424	
20. [#13 or #14 or #15 or #16 or #17 or #18 or #19]	**663024**	**116151**
21. [#12 and #20]	**2065**	**394**
22. (MH "Motor Activity")	8945	
23. (MH "Exercise")	32620	
24. Physical Exertion	289	
25. (MH "Walking")	14898	
26. (MH "Movement")	9748	
27. Exercise Therapy	2954	
28. (MH "Leisure Activities")	5444	
29. (MH "Physical Fitness")	11512	
30. (MH"physical activity")	24083	
31. [#22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30]	**97804**	**10113**
32. [#21 and #31]	**337**	**58**
MH –Exact subject heading "…" – free text term (used when no exact subject heading was available) *truncation #wildcard		

Cochrane

Search terms	No of records returned	Updated search
For *Cochrane library (1993 – Jan 2018)*	***June 2016***	***Jan 2018***
1. MeSH descriptor: [Pregnancy]	6321	
2. MeSH descriptor: [Pregnant Women]	122	
3. MeSH descriptor: [Prenatal Care]	1203	
4. #1 or #2 or #3	**7210**	**678**
5. MeSH descriptor: [Diabetes, Gestational]	459	
6. MeSH descriptor: [Body Weight]	18942	
7. MeSH descriptor: [Weight Gain]	1876	
8. MeSH descriptor: [Overweight]	10086	
9. MeSH descriptor: [Obesity]	9187	
10. MeSH descriptor: [Body Mass Index]	7517	
11. #5 or #6 or #7 or #8 or #9 or #10	**22600**	**917**
12. #4 and #11	**707**	**481**
13. MeSH descriptor: [Health Behavior]	17663	
14. MeSH descriptor: [Life Style]	3530	
15. intervention	115332	
16. behav*	77578	
17. behavio?r	11697	
18. program?e	16593	
19. change 9	90017	
20. #13 or #14 or #15 or #16 or #17 or #18 or #19	**235528**	**1675**
21. #12 and #20	**289**	**480**
22. MeSH descriptor: [Motor Activity]	19579	
23. MeSH descriptor: [Exercise]	16790	
24. MeSH descriptor: [Physical Exertion]	3505	
25. MeSH descriptor: [Walking]	3151	
26. MeSH descriptor: [Movement]	23338	
27. MeSH descriptor: [Exercise Therapy]	9086	
28. MeSH descriptor: [Leisure Activities]	13852	
29. MeSH descriptor: [Physical Fitness]	2444	
30. MeSH descriptor: [Motor Activity]	19579	
31. #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30	**35152**	**739**
32. #21 and #31	**60**	**254**
MeSH descriptor (Medical subject heading) *truncation ?wildcard		

EMBASE

Search terms	No of records returned	Updated search
For *EMBASE (1947 – Jan 2018)*	***June 2016***	***Jan 2018***
1. 'Pregnancy'/exp	654342	
2. 'Pregnant Women'/exp	46339	
3. 'Prenatal Care'/exp	121687	
4. [#1 or #2 or #3]	**732085**	**70953**
5. 'Diabetes, Gestational'/exp	24837	
6. 'Body Weight'/exp	492033	
7. 'Weight Gain'/exp	77604	
Overweight	/	
8. 'Obesity'/exp	366253	
9. 'Body Mass'/exp	245340	
10. [#5 or #6 or #7 or #8 or #9]	**900504**	**122083**
11. [#4 and #11]	**78264**	**9158**
12. behav*	1739263	
13. behavio?r	219723	
14. 'Health Behavior'/exp	304440	
15. 'Life Style'/exp	85097	
16. Intervention	629575	
17. Program?e	128868	
18. Change	1075019	
19. [#12 or #13 or #14 or #15 or #16 or #17 or #18]	**3447254**	**361533**
20. [#11 and #19]	**13558**	**1943**
21. 'Motor Activity'/exp	424415	
22. 'Exercise'/exp	253718	
Physical Exertion	/	
23. 'Walking'/exp	79603	
24. 'Movement (physiology)' /exp	317771	
25. 'Kinesiotherapy'/exp	57036	
26. 'Leisure'/exp	24099	
27. 'Fitness' /exp	33137	
28. 'physical activity' /exp	286628	
29. [#22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30]	**1087669**	**98229**
30. [#21 and #31]	**1919**	**476**
Not available as Emtree terms – Overweight/ Physical Exertion • 'Movement (physiology)' - movement • 'Kinesiotherapy' – exercise therapy *truncation ?wildcard		

PubMed

Search terms	No of records returned	Updated search
For *PubMed (1996 – Jan 2018)*	***June 2016***	***Jan 2018***
1. Pregnancy	848096	
2. Pregnant Women	87616	
3. Prenatal Care	36250	
4. [#1 or #2 or #3]	**861750**	**20370**
5. Diabetes, Gestational	15138	
6. Body Weight	525646	
7. Weight Gain	68353	
8. Overweight	181872	
9. Obesity	240033	
10. Body Mass Index	172157	
11. [#5 or #6 or #7 or #8 or #9 or #10]	**698688**	**20763**
12. [#4 and #11]	**72005**	**2425**
13. behav*	1424816	
14. behaviour	1845255	
15. Health Behavior	330291	
16. Lifestyle	121976	
17. Intervention	427292	
18. Programme	89461	
19. Change	857962	
20. [#13 or #14 or #15 or #16 or #17 or #18 or #19]	**3289519**	**809804**
21. [#12 and #20]	**16973**	**1691**
22. Motor Activity	267074	
23. Exercise	319266	
24. Physical Exertion	56892	
25. Walking	59762	
26. Movement	583411	
27. Exercise Therapy	88149	
28. Leisure Activities	188085	
29. Physical Fitness	33970	
30. physical activity	359556	
31. [#22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30]	**985231**	**90904**
32. [#21 and #31]	**2733**	**185**
MeSH terms limited the result numbers so free txt terms where searched #? Wildcard not available in PubMed		

Table 28: Data Extraction Form

Physical activity interventions for overweight and obesity during pregnancy: A systematic review of behaviour change interventions

Date of data extraction:	**Name of reviewer:**
Paper title:	
First Author:	**Year/volume/pages:**
Comments (include links to other studies)	
Type of interventions (please tick): Physical activity/exercise only ☐ Physical activity /exercise & diet ☐ Other ☐ If so, specify_________________	
Participant group (i.e. inclusion criteria, such as pregnant, BMI(≥25))	
Indicate whether a measure of sedentary behaviour/ sitting down was documented:	
Country:	
Source of funding:	**Ethical approval (please tick)** **Yes** ☐ **No** ☐

1. Study Design

Design of Study:	**Please tick:**
1. Randomised controlled trials	
2. Non-randomised controlled trials	
3. Quasi-experimental	
4. Quasi-RCT	
5. Unsure/not stated	
6. Other (please state)	

2. Intervention

Based on the WIDER[1] Recommendation to improve reporting of the content of behaviour change interventions

2.1 Characteristics of participants

Participants	Intervention group 1	Intervention group 2	Control group	Overall
No. of participants (number receiving the intervention)				
Mean age (SD)				
Weeks pregnant (SD)				
BMI (SD)				
Ethnicity: White(No.) Non-white (No.)				
Parity				
Socio-demographic status				
Other				

2.2 Delivered by

Delivered by	Please tick
1. Researcher	
2. Nurse	
3. Physiotherapists	
4. GP	
5. Peers	
6. Health and Fitness Professionals	
7. Lay expert	
8. Midwife	
9. Other, please specify	
10. Not stated	

2.3 Setting

Setting:	Please tick
1. Hospital/ clinic	
2. College / University	
3. GP Surgery	
4. Community centre	
5. By Post	
6. By Telephone	

[1] Workgroup for Intervention Development and Evaluation Research (WIDER) group

7. Participants home	
8. Online/email	
9. Gym/leisure centre	
10. Other, please specify	
11. Not stated	

2.4 Mode of delivery

Delivery Mode	Please tick
1. Discussion/ meeting group	
2. Telephone	
3. Self-help manuals	
4. Media	
5. Postal	
6. Other, please specify	
7. Not stated	

3. Description of intervention content

Group definition/description
Intervention group 1
Description (e.g. treatment group/ theory based intervention):
Intervention group 2
Description:
Control group
Description (e.g. comparison group, wait list control/ usual care):

3.1 Intervention detail

Intervention type	Please tick
1. Group intervention	
2. Individual intervention	
Behaviour target for intervention (type/frequency):	
Duration of intervention (time, weeks months):	
Number of intervention contact sessions (contact time):	
Theoretical basis	**Please tick**
1. Explicitly mentioned	
2. Some theory cited	

3. No theory cited	
What is the theory mentioned	
1. Social Cognitive Theory	
2. Trans Theoretical Model	
3. Theory of Planned Behaviour	
4. Protection Motivation Theory	
5. Self Determination Theory	
6. Unclear	
7. Other, please specify	
8. Not stated	

Time
Time point of main analysis (i.e. time between baseline measure and post intervention measure)

3.2 Intervention outcomes

Intervention Characteristics	Please tick
Primary outcome of intervention	
1. Exercise (e.g. aerobics, gym, jogging)	
2. Physical activity (e.g. lifestyle activities, gardening, walking)	
3. Weight management	
4. Other, specify	
Please specify physical activity (e.g. frequency/duration)	
Outcomes	
Behavioural measure (e.g. walking, physical activity)	
Measurement tool (e.g. validated questionnaire, survey, pedometer)	
Types of measure (please tick) **S**ubjective ☐ Objective ☐	

Other outcomes reported	Tick	Give details
1. Psychological variables		
2. Gestational weight gain		
3. Gestational diabetes (GDM)		
4. Dietary behaviour		
5. Mental health		
6. Maternal physical health		

7. Child health		
8. Sedentary behaviour		
9. Other		

4. Access to additional intervention information (e.g. protocols/manuals)

Where is the intervention described?	
1. All in this paper	
2. All described elsewhere (e.g. protocols)	
3. Additional information described elsewhere	
4. Based on another study, described elsewhere	
If 1, 2 or 3 please state the references for the paper:	

5. Detailed description of active control condition[2] *(Skip if no control condition available)*

Control delivered by:
Control setting:
Delivery Mode for the control condition
Duration of control (time, weeks months):
Number of control contact sessions (contact time):

[2] Note the active control condition (e.g. 'if the control treatment is usual care, authors should report all the components received by the control group')

6. **PHYSICAL ACTIVITY BEHAVIOUR DATA**

Results						
Statistical techniques used :						
Reliability of measure:						
Time point 1:				**Between group differences**		
Primary outcome	Group 1 (Mean and SD)	Group 2 (Mean and SD)	Control (Mean and SD)	Effect size	P-value	Test statistic
Physical activity						
Time point 2:						
Primary outcome	Group 1 (Mean and SD)	Group 2 (Mean and SD)	Control (Mean and SD)	Effect size	P-value	Test statistic
Physical activity						
Time point 3:						
Primary outcome	Group 1 (Mean and SD)	Group 2 (Mean and SD)	Control (Mean and SD)	Effect size	P-value	Test statistic
Physical activity						
Time point 4						
Primary outcome	Group 1 (Mean and SD)	Group 2 (Mean and SD)	Control (Mean and SD)	Effect size	P-value	Test statistic
Physical activity						

Over time change	**Effect size**			
	P-value			
	Test statistic			

7. Quality Assessment: The Cochrane Collaboration's tool for assessing risk of bias

Domain		Level of risk (High/low/ unknown)	Support for judgement
Selection bias.	**1. Random sequence generation.** *Selection bias (biased allocation to interventions) due to inadequate generation of a randomised sequence*		*(Describe the method used to generate the allocation sequence in sufficient detail to allow an assessment of whether it should produce comparable groups)*
	0. **Allocation concealment.** *Selection bias (biased allocation to interventions) due to inadequate concealment of allocations prior to assignment.*		*(Describe the method used to conceal the allocation sequence in sufficient detail to determine whether intervention allocations could have been foreseen in advance of, or during, enrolment)*
Performance bias.	1. **Blinding of participants and personnel** *Performance bias due to knowledge of the allocated interventions by participants and personnel during the study.*		*(Describe all measures used, if any, to blind study participants and personnel from knowledge of which intervention a participant received. Provide any information relating to whether the intended blinding was effective)*
Detection bias.	2. **Blinding of outcome assessment** *Detection bias due to knowledge of the allocated interventions by outcome assessors*		*Describe all measures used, if any, to blind outcome assessors from knowledge of which intervention a participant received. Provide any information relating to whether the intended blinding was effective.*
Attrition bias.	3. **Incomplete outcome data** *Attrition bias due to amount, nature or handling of incomplete outcome data.*		*(Describe the completeness of outcome data for each main outcome, including attrition and exclusions from the analysis. State whether attrition and exclusions were reported, the numbers in each intervention group (compared with total randomized participants), reasons for attrition/exclusions where reported, and any re-inclusions in analyses performed by the review authors)*
Reporting bias.	4. **Selective reporting.** *Reporting bias due to selective outcome reporting.*		*(State how the possibility of selective outcome reporting was examined by the review authors, and what was found)*
Other bias.	5. **Other sources of bias.** *Bias due to problems not covered elsewhere in the table.*		*(State any important concerns about bias not addressed in the other domains in the tool. If particular questions/entries were pre-specified in the review's protocol, responses should be provided for each question/entry)*

8. **Behaviour Change techniques used in the intervention**

Description of each BCT utilised							
BCT number	Cluster	BCT	Present? Y or N	Was it reported as a BCT? Y or N	Presence ++ BCT present beyond all reasonable doubt + in all probability blank- none	Number of times BCT was utilised	Provide added information on how the BCT was presented
1.1	Goals and planning	Goal setting (behaviour)					
1.2		Problem solving					
1.3		Goal setting (outcome)					
1.4		Action planning					
1.5		Review behaviour goal(s)					
1.6		Discrepancy between current behaviour and goal					
1.7		Review outcome goal(s)					
1.8		Behavioural contract					
1.9		Commitment					
2.1	Feedback and monitoring	Monitoring of behaviour by others without feedback					

2.2		Feedback on behaviour					
2.3		Self-monitoring of behaviour					
2.4		Self-monitoring of outcome(s) of behaviour					
2.5		2.5. Monitoring of outcome(s) of behaviour without feedback					
2.6		Biofeedback					
2.7		Feedback on **outcome**(s) of behaviour					
3.1	Social support	Social support (unspecified)					
3.2		Social support (practical)					
3.3		Social support (emotional)					
4.1	Shaping knowledge	Instruction on how to perform the behaviour					
4.2		Information about antecedents					
4.3		Re-attribution					

4.4		Behavioural experiments					
5.1	Natural consequences	Information about health consequences					
5.2		Salience of consequences					
5.3		Information about social and environmental consequences					
5.4		Monitoring of emotional consequences					
5.5		Anticipated regret					
5.6		Information about emotional consequences					
6.1	Comparison of behaviour	Demonstration of the behaviour					
6.2		Social comparison					
6.3		Information about others' approval					
7.1	Associations	Prompts/cues					
7.2		Cue signalling reward					
7.3		Reduce prompts/cues					

7.4		Remove access to the reward					
7.5		Remove aversive stimulus					
7.6		Satiation					
7.7		Exposure					
7.8		Associative learning					
8.1	Repetition and substitution	Behavioural practice/rehearsal					
8.2		Behaviour substitution					
8.3		Habit formation					
8.4		Habit reversal					
8.5		Overcorrection					
8.6		Generalisation of target behaviour					
8.7		Graded tasks					
9.1	Comparison of outcomes	Credible source					
9.2		Pros and cons					
9.3		Comparative imagining of future outcomes					
10.1	Reward and threat	Material incentive (behaviour)					

10.2		Material reward (behaviour)					
10.3		Non-specific reward					
10.4		Social reward					
10.5		Social incentive					
10.6		Non-specific incentive					
10.7		Self-incentive					
10.8		Incentive (outcome)					
10.9		Self-reward					
10.10		Reward (outcome)					
10.11		Future punishment					
11.1	Regulation	Pharmacological support					
11.2		Reduce negative emotions					
11.3		Conserving mental resources					
11.4		Paradoxical instructions					
12.1	Antecedents	Restructuring the physical environment					
12.2		Restructuring the social environme					

		nt					
12.3		Avoidance/ reducing exposure to cues for the behaviour					
12.4		Distraction					
12.5		Adding objects to the environme nt					
12.6		Body changes					
13.1	Identit y	Identificati on of self as role model					
13.2		Framing/ reframing					
13.3		Incompatibl e beliefs					
13.4		Valued self-identify					
13.5		Identity associated with changed behaviour					
14.1	Sched uled conse quenc es	Behaviour cost					
14.2		Punishment					
14.3		Remove reward					
14.4		Reward approximat ion					
14.5		Rewarding completion					

14.6		Situation-specific reward					
14.7		Reward incompatible behaviour					
14.8		Reward alternative behaviour					
14.9		Reduce reward frequency					
14.10		Remove punishment					
15.1	Self-belief	Verbal persuasion about capability					
15.2		Mental rehearsal of successful performance					
15.3		Focus on past success					
15.4		Self-talk					
16.1	Covert learning	Imaginary punishment					
16.2		Imaginary reward					
16.3		Vicarious consequences					

Additional comment

11 APPENDIX E: PUBLISHED PAPERS

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RESEARCH ARTICLE Open Access

Enablers and barriers to physical activity in overweight and obese pregnant women: an analysis informed by the theoretical domains framework and COM-B model

C. Flannery[1*], S. McHugh[2], A. E. Anaba[2], E. Clifford[3], M. O'Riordan[4], L. C. Kenny[5], F. M. McAuliffe[6], P. M. Kearney[2] and M. Byrne[1]

Abstract

Background: Obesity during pregnancy is associated with increased risk of gestational diabetes mellitus (GDM) and other complications. Physical activity is a modifiable lifestyle factor that may help to prevent these complications but many women reduce their physical activity levels during pregnancy. Interventions targeting physical activity in pregnancy are on-going but few identify the underlying behaviour change mechanisms by which the intervention is expected to work. To enhance intervention effectiveness, recent tools in behavioural science such as the Theoretical Domains Framework (TDF) and COM-B model (capability, opportunity, motivation and behaviour) have been employed to understand behaviours for intervention development. Using these behaviour change methods, this study aimed to identify the enablers and barriers to physical activity in overweight and obese pregnant women.

Methods: Semi-structured interviews were conducted with a purposive sample of overweight and obese women at different stages of pregnancy attending a public antenatal clinic in a large academic maternity hospital in Cork, Ireland. Interviews were recorded and transcribed into NVivo V.10 software. Data analysis followed the framework approach, drawing on the TDF and the COM-B model.

Results: Twenty one themes were identified and these mapped directly on to the COM-B model of behaviour change and ten of the TDF domains. Having the social opportunity to engage in physical activity was identified as an enabler; pregnant women suggested being active was easier when supported by their partners. Knowledge was a commonly reported barrier with women lacking information on safe activities during pregnancy and describing the information received from their midwife as 'limited'. Having the physical capability and physical opportunity to carry out physical activity were also identified as barriers; experiencing pain, a lack of time, having other children, and working prevented women from being active.

Conclusion: A wide range of barriers and enablers were identified which influenced women's capability, motivation and opportunity to engage in physical activity with "knowledge" as the most commonly reported barrier. This study is a theoretical starting point in making a 'behavioural diagnoses' and the results will be used to inform the development of an intervention to increase physical activity levels among overweight and obese pregnant women.

Keywords: Overweight, Obesity, Pregnant women, Maternal health, Physical activity, Theoretical domains framework, COM-B model, Behaviour change wheel

* Correspondence: cflannery@ucc.ie
[1]Health Behaviour Change Research Group, School of Psychology, National University of Ireland, Galway, Ireland
Full list of author information is available at the end of the article

Background

Recent studies identify increasing trends in maternal obesity worldwide and associated complications such as gestational diabetes mellitus (GDM) [1–3]. Maternal obesity also has adverse neonatal outcomes, such as macrosomia [4] and offspring born to obese women are more likely to develop obesity, type 2 diabetes, cardiovascular disease and cancer in later life [5]. A recent systematic review identified maternal pre-pregnancy overweight as a significant risk factor for childhood overweight [6]. Children of mothers who were overweight before pregnancy were 1.37 times more likely to be overweight at 3 years of age than children of normal weight parents [7]. These trends and risks have increased interest in antenatal interventions which focus on women's eating, physical activity, their impact on gestational weight gain and GDM [8–10]. Strong evidence exists on the benefits associated with physical activity during pregnancy including an increase in functional mobility and a reduction in nausea and vomiting [11, 12]. Higher levels of physical activity before pregnancy or in early pregnancy also significantly lowers the risk of developing GDM [13]. A recent meta-analysis reported that antenatal physical activity in women of any body mass index led to a small reduction in offspring birth weight [14]. It is possible that this modest reduction in birth weight in offspring of overweight and obese women may be beneficial in reducing the long-term obesity risk [14, 15]. Furthermore, behavioural changes made during pregnancy may continue after childbirth and possibly throughout the woman's life [16] which in turn may have positive effects on child physical activity levels [17].

Despite these benefits, women's physical activity levels often reduce or cease during pregnancy [18]. Similar to Health Service Executive (HSE) recommendations in Ireland, the American Congress of Obstetricians and Gynaecologists (ACOG) and the Royal College of Obstetricians and Gynaecologists (RCOG), UK, recommend 30 min of daily moderate intensity physical activity for pregnant women [19–22]. Previous studies, carried out in different countries, reported low rates of physical activity during pregnancy. In the United States, only 15.8% of pregnant women vs. 26.1% of non-pregnant women reported engaging in the recommended physical activity guidelines [7]. This figure was even lower in a study from Brazil, where only 4.7% of pregnant women were physically active [8]. Only one-fifth of pregnant women in Ireland met the recommended guidelines and over 10% reported no physical activity [23]. Furthermore, a study examining lifestyle changes using the Pregnancy Risk Assessment Monitoring system (PRAMS), Ireland found that adherence to physical activity guidelines of moderate intensity activity was low (12.3%) but was particularly low for pregnant women with a body mass index >25 kg/m^2 (6.4%) [24]. A cross-sectional study carried out in Danish women who wore a pedometer for at least 5 days, found that mean footsteps were higher among normal-weight women compared to obese women [25]. Furthermore, a decline in physical activity in pregnancy was found in a study carried out in 305 overweight or obese women [26]. These low rates of physical activity during pregnancy, particularly for overweight and obese women, are concerning given the significant health benefits for both mother and baby [12].

Previous research on clinical effects of lifestyle interventions in overweight and obese pregnant women has shown conflicting results [27–31]. These results have been attributed to poor study design, lack of power, lack of consistency in terms of the target behaviour, and failing to identify the psychological determinants and behavioural mechanisms by which the intervention is expected to have an effect [32, 33]. These complex lifestyle interventions have consisted of interacting components including dietary and physical activity counselling, monitoring of weight and group exercise sessions or have been designed to prevent excessive gestational weight gain (GWG) and reduce the risk of GDM [34]. Other interventions include individual counselling sessions on weight control and motivational interviewing [35, 36]. Most of these studies have examined the combined effect of physical activity and dietary advice and guidance. Three randomized controlled trials (RCTs) [31, 37, 38] that assessed the isolated effects of exercise in pregnancy on GWG and clinical outcomes in overweight and obese women found no significant difference in GWG between exercise and control groups. However, a recent meta-analysis [39], found that structured physical exercise programs during pregnancy do decrease the risk of GDM. Future research needs to address these conflicting results, hence, there is a need to establish the potential effects of physical activity on clinical indicators, especially in overweight and obese pregnant women.

Using theory to identify the determinants of behaviour can increase the likelihood that an intervention will be effective [40, 41]. A systematic review [42] examining the determinants of physical activity during pregnancy found that intention to exercise, self-efficacy and barriers such as lack of time and tiredness were strong predictors of exercise. Moreover, a systematic review that evaluated the content of physical activity interventions in pregnancy found theoretically developed interventions were more likely to help reduce the decline of physical activity throughout pregnancy [43]. Therefore, more attention should be placed on using theory to identify perceived determinants of behaviour and barriers to physical activity behaviour in pregnancy in order to develop effective interventions.

Health psychology offers theories of behaviour that can be used in maternity care interventions to help women make changes to lifestyle behaviours [34, 43, 44].

Michie and colleagues developed a framework derived from 33 commonly used behavioural theories and 128 psychological constructs called The Theoretical Domains Framework (TDF). The TDF has been identified as a useful tool for identifying determinants of behaviour and barriers to behaviour change. The TDF is an elaboration of the COM-B model which stands for "capability", "opportunity", "motivation" and "behaviour" [45, 46](Fig. 1). The COM-B model proposes that for any behaviour to occur a person must have the psychological and physical capability to perform the behaviour; the physical and social opportunity to engage in it and must be motivated to do so. Furthermore, when little is known about the population, qualitative research is useful to develop a theoretical understanding of the target behaviour [47–50]. To date, a number of empirical studies have used either the TDF or COM-B in order to develop behaviour change interventions in different contexts [51, 52] but to our knowledge this has not yet been done for physical activity in an overweight and obese pregnant population.

Therefore, the aim of this study was to use the TDF and corresponding COM-B model to identify enablers and barriers to physical activity in overweight and obese pregnant women, and to use this information to inform the development of an antenatal lifestyle intervention to improve physical activity levels during pregnancy.

Method

Study design

A qualitative approach was used. Semi-structured interviews were conducted with a sample of overweight and obese pregnant women at risk of GDM. Ethical approval was obtained from the University College Cork Clinical Research Ethics Committee of the Cork Teaching Hospitals (ref: ECM 4 (y) 06/01/15).

Sampling and recruitment

Medical chart review identified a purposive sample of pregnant women with a body mass index (≥25 kg/m^2) recruited during pregnancy from a public antenatal clinic at Cork University Maternity Hospital (CUMH). CUMH is a large academic maternity hospital in the South of Ireland where approximately 6657 new obstetrics patients entered in 2015 [53]. Eligible participants were approached individually and informed about the study by the attending midwife and researcher on site at their antenatal appointment. They were

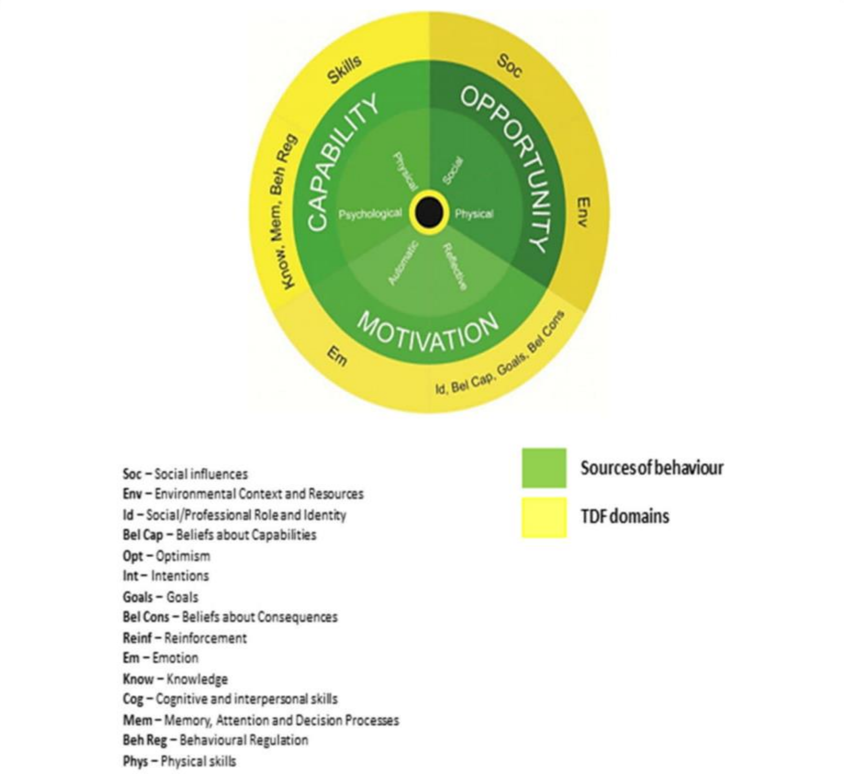

Fig. 1 Theoretical domains framework an elaboration of the COM-B model. Reproduced with permission from Michie et al. [45, 46]

also provided with an information leaflet explaining the purpose of the study, how to participate and offered a small monetary compensation for participation. A €20 'One for All' voucher for a local shopping centre was posted to each woman who participated once the interview had been completed. Simultaneously, a sub-study examining diet and physical activity behaviours in pregnant African women led by researcher (AEA) was on-going. These women were recruited from the same antenatal clinic, during the same period using the same sampling criteria and interview guide. Therefore, interview data on physical activity for these women were included in this analysis. Data on age, nationality, body mass index (BMI) and gestational age were recorded from medical charts where possible. GDM, employment status and miscarriages were recorded only for those women who reported them spontaneously during the interview.

Interview process

Written informed consent was obtained from all participants at the start of the interviews. Face-to-face interviews were carried out in the antenatal clinic in CUMH on a day and time suitable for the participant by two researchers (CF) and (AEA) between June and September 2015. A semi-structured interview schedule was developed based on existing literature [34, 43, 54–56] and was used to facilitate the discussion (see Table 1). It consisted of open-ended questions and prompts about current lifestyle behaviours (physical activity and diet), challenges to engaging in healthy lifestyle and support mechanisms available. The interview schedule and process were piloted by interviewing two pregnant women at University College Cork. Following this pilot, additional probes and prompts were included to further explore women's experiences in terms of weight management and lifestyle changes. Pilot interviews were not included in the final sample as the women were not eligible for inclusion in the study.

Data analysis

Interviews were recorded and transcribed verbatim. NVivo software was used to facilitate data analysis. Data

Table 1 Interview schedule used to facilitate the interviews

	Questions	Prompts/Probes
Intro	Tell me a little about your home life?	• First pregnancy? • Married, single? • Other Children – how many? • Employed – how many hours you work?
	Tell me a bit about your lifestyle at the moment?	• Diet – cravings, nausea • **PA** – active before pregnancy, frequency, duration • Have diet/**PA** patterns changed since pregnancy? • In what way and why?
Health	Has a HCP made you aware of the risks surrounding your pregnancy	• Excessive weight gain • GDM • Potential difficulties during delivery • How does that make you feel?
PA and Diet	What **PA** do you/would you like doing?	• Walking, running, exercises tailored for pregnancy, sports, gym?
	How important do you feel exercise and **PA** is during pregnancy?	• Fitness level • Mobility • Give you more energy • Help sleep
	Tell me what you think would be the best way to encourage women to be watchful of diet and **PA** during pregnancy?	• Through friends, other pregnant women, GP, nurses, information sessions, individual or group, exercise and diet programmes
Behaviour Change	Have you been given advice about dietary habits and **PA** since you became pregnant?	• HCP, family, friend, book, internet? • When was this? • How did you feel about the advice?
	What to do think are the main challenges to **PA** and diet changes during pregnancy?	• Lack of information/ support/ time/ resources
	Would you be interested in using technology to help you track and improve you **PA** and diet	• Mobile phone apps, text message/phone, web based information forums, pedometer? • Would these support mechanisms be useful? • If it provided you with information as well • If it provided you HCP with your information
	How would you feel about participating in a study where technology would be used as encouragement to increase **PA**?	• Mobile phone apps, text message/phone, web based information forums, pedometer • Access to internet, mobile phone
	Is there anything I haven't asked you today you would like to mention?	

PA Physical activity, *HCP* Health care professional, *GDM* Gestational diabetes mellitus analysis followed a framework approach [57]. An inductive thematic analysis was conducted to identify new emerging themes and to investigate a priori objectives using the TDF and COM-B model. Each transcript was read and re-read numerous times by the researcher (CF). Transcripts were coded line by line and analysed to identify similarities and differences. Following open-coding, broader categories were mapped onto the domains of the TDF and then, directly onto the six components of the COM-B model identifying emerging themes relating to enablers and barriers to physical activity. See Table 3 for description of the TDF domains and components of the COM-B model. All transcripts were coded by the researcher (CF) and a subset of interviews were independently coded and analysed by a second researcher (SMH). Minor differences arose in relation to the mapping of codes to the TDF domains, particularly when codes mapped to more than one domain. Differences were resolved by consensus involving a third researcher with expertise in using the TDF and COM-B model (MB) on one occasion, as some themes were coded into multiple TDF domains. Specifically, the domain of "behavioural regulation" and "goals" were merged due to the overlapping theme of action planning. Recruitment continued until new issues ceased to emerge and saturation occurred across the theoretical domains. Two further pregnant women were interviewed to check if any new themes emerged.

Results

Participants' characteristics

In total twenty two overweight and obese pregnant women were interviewed. Data saturation occurred at interview twenty, as subsequent interviews did not contribute to the development of new themes. Eight interviews were included from the sub-study giving the overall sample of thirty overweight and obese pregnant women. Table 2 provides details of the participants' characteristics including age, nationality, BMI and gestational age. GDM, employment status and miscarriages were only recorded if mentioned by the woman during the interview.

Physical activity clusters identified in pregnancy

From the open coding of the interview data, pregnant women identified a number of factors surrounding physical activity in pregnancy. Given the importance of physical activity during pregnancy and in order to highlight pregnant women's perceptions, these different factors were categorised into four clusters that focus around friends and family, pregnancy, antenatal care and the community. These clusters are summarised in Fig. 2. Participants discussed different types of physical activity in pregnancy, the resources available and how family and friends could provide an important supportive role in physical activity participation. Participants also described the context in which these physical

Table 2 Profile characteristics of participants ($N = 30$)

Nationality	
Chinese	2
French	1
Hungarian	1
Lithuanian	1
Irish	16
Nigerian	5
Sudanese	2
Congolese (Democratic Republic of Congo)	1
Ghanaian	1
Age	
20–29	6
30–39	14
40+	1
Unknown[a]	9
Gestation	
First Trimester (0 to 13 Weeks)	1
Second Trimester (14 to 26 Weeks)	8
Third Trimester (27 to 40 Weeks)	20
Not stated	1
BMI (kg/m2\)[b]	
Overweight 25–29	12
Obese ≥30	12
Unknown[c]	6
Pregnancy	
Singleton	29
Twins	1
Employment	
Working full time	10
Working part time	2
Out sick from work	2
Not working	6
Not stated	10
Gestational Diabetes Mellitus[d]	
GDM	5
Not stated	25
Miscarriages[e]	
Miscarriages	8
Not stated	22

[a]Not recorded from medical chart
[b]BMI taken from medical chart (calculated at booking visit by midwife)
[c]Midwife identified women as overweight and obese from chart but did not record BMI
[d]Only 5 women mentioned having gestational diabetes
[e]Only 8 women discussed having one or more miscarriages

activity behaviours occur. Certain factors identified within these clusters are also present in the TDF and COM-B analysis, see results below. The main type of physical activity identified by the pregnant women includes walking, swimming, pilates, yoga and physical activity classes tailored for pregnancy.

Summary of the TDF and COM-B model: Barriers and enablers to physical activity

Twenty one themes were identified that mapped directly onto ten of the TDF domains and the six COM-B components. The ten TDF domains included "skills", "knowledge", "behavioural regulation", "goals"; "environmental context and resources", "social influences", "social/professional role and identity", "beliefs about capability", "intentions", and "emotion". The TDF domains not relevant to the context of physical activity in overweight and obese pregnant women were "optimism", "reinforcement" "memory" and "belief about consequences". These findings are described in greater detail below using the TDF and corresponding COM-B model (Table 3).

Capability

Physical skills

In terms of the domain "physical skills", pregnancy related symptoms were a common reason given by participants for undertaking little or no physical activity. These included muscle pain, pelvic or lower back pain, swelling and other conditions.

> *'The problems I had just stopped me [PA]. Like I got a polyp…which was heavy bleeding and the more I strained the body, even just a swim it was just like there was more pressure on it so I just said it was better to cut everything' (Participant 15; 32 weeks pregnant)*

Furthermore, women who knew their pregnancy was high risk, decided themselves, that it was best not to engage in physical activity.

> *'I'm a high risk pregnancy so I couldn't do any of the exercise then on this pregnancy. And then I have factor 5 blood so really clotting and all that, I have to take it easy' (Participant 05; 28 weeks pregnant)*

Another barrier was that of feeling too tired to engage in physical activity; finding it hard to move, lack of energy and being physically drained.

> *'It's harder to move faster now that I am pregnant. Like sometimes I have energy and some days I don't… It's*

Fig. 2 Physical activity clusters identified from the pregnant women interviews

Table 3 Mapping of themes to the TDF domains and COM-B model

Themes	TDF	COM-B
- Fitness level prior to pregnancy - House work as a form of PA - Medical conditions and pregnancy symptoms (pain/energy/ tiredness)	Knowledge (awareness of the existence of something: knowledge of condition)	Psychology capability Knowledge or psychological skills, strength or stamina to engage in the necessary mental process
- Limited knowledge surrounding PA benefits, types of PA in pregnancy and PA resources - Pregnant women discussed concerns around having that 'conversation'	Knowledge (awareness of the existence of something: knowledge of condition)	Psychology capability Knowledge or psychological skills, strength or stamina to engage in the necessary mental process
- Self- monitoring, use of pedometer/step count/phone apps	Behavioural regulation (managing or changes action – self monitoring)	
- Women expressed interest in goal setting	Goals[a] (mental representations of outcome or end states, that an individual wants to achieve)	
- Pregnant woman's situation (family life/children/work/pets) - Financial situation - Weather/ built environment and resources within the community	Environmental context and resources (persons situation or environment)	Physical Opportunity Opportunity afforded by the environment involving time, resources, location, cues physical affordance
- Acknowledged support from family members, partner and friends - Interaction with other pregnant women [PA classes] was mentioned	Social influences (Process that can change thoughts feelings or behaviours – social pressure)	Social opportunity Opportunity afforded by interpersonal influences, social cues and cultural norms that influence the way we think
- 'Every pregnant women is different' - Differences in pregnancies	Social role and identity (set of behaviours and displayed personal qualities in a social or work setting)	Reflective Motivation Reflective process involving plans (self-conscious intentions) and evaluations (beliefs about what is good and bad)
- Using pregnancy as an 'excuse' - Concern for health of the baby - Feeling responsible - Difficulty breaking habits/mind-set	Beliefs about capability (acceptance of the truth, reality or validity about an ability, perceived behavioural control,, self-esteem, confidence)	
- Post-partum intentions (planning weight loss/healthy lifestyle)	Intentions (A conscious decision to perform a behaviour)	Reflective Motivation Reflective process involving plans (self-conscious intentions) and evaluations (beliefs about what is good and bad)
- Feelings of worry, concern and guilt during pregnancy - Fear based on previous pregnancy outcome/miscarriage	Emotion (complex reactions - fear, anxiety, affect, stress, depression, positive and negative effect, burn out)	Automatic Motivation Automatic processes involving emotional reactions, desires(wants and needs) impulses inhibitions drive states and reflex responses

[a]Behavioural regulation and goals were merged due to the overlapping construct of 'action planning'
TDF domain not identified: optimism, reinforcement and belief about consequences

difficult, like you feel like you want to do stuff but you can't, your body is just tired and drained physically' (Participant 20; 28 weeks pregnant)

However, some women felt that physical activity during pregnancy did benefit them (e.g. helped them wake up, gave them energy and made them feel good). Likewise, being physically fit before pregnancy was identified as an enabler; if a woman was active before pregnancy she was more likely to keep it up.

'I don't know I think it depends on everyone's circumstances. Like a lot of women would be fit before they got pregnant and they would keep up their walking or running' (Participant 01; gestation unknown)

House work emerged as an enabler particularly for women who did not like exercise. These women considered household activities as part of their daily activity.

'No I wouldn't get out and walk or anything like that… housework would be my activity during the day' (Participant 04; 28 weeks pregnant)

'Not really, there's nothing really, I'm not a big fan of exercise. I will do the house work, the cleaning and the cooking' (Participant 17; 36 weeks pregnant)

Knowledge

When considering the domain of "knowledge" there was concerns about safety and types of exercise appropriate in pregnancy.

> *'To be honest, I'm not good in what physical activities a pregnant woman should do because nobody really has told me about the kind of exercise you should be doing' (Participant 28; 32 weeks pregnant).*

> *'I mean I don't know can you do certain exercises so I would be worried that I could pull a muscle so I would be extra cautious I suppose at the gym cause I'm afraid and I wouldn't really know' (Participant 13; 32 weeks pregnant)*

These doubts were partly due to the limited information they reported receiving from their midwife or health care professional. This information was described as a *'limited', 'quick', 'automatic', 'like a checklist'* and women felt the benefits of physical activity was rarely discussed.

> *'It's very limited really, very limited. It's a quick one minute conversation really in relation to it [PA/ Diet]....I suppose nobody really sits you down to go through the implications of that or the benefits and stuff like that' (Participant 21; 26 weeks pregnant)*

Furthermore when discussing 'the conversation' women felt more emphasis was placed on the clinical aspect of the visit rather than information and advice.

> *'They don't tend to offer any advice good or bad in terms of weight management and activity and stuff like that. It's more the blood pressure, checking the baby and stuff like that' (Participant 21; 26 weeks pregnant)*

Some women felt that midwives assumed because they had other children they already had knowledge and information around being physically active in pregnancy.

> *'...what I found different was when they know that you have children already they kind of thinking that you know everything which is not true...you may forget, years apart, like between now and the last time I had a baby there is a three year gap so I can't remember everything but they seem to assume because you have had other children you know already what to do' (Participant 28; 32 weeks pregnant)*

Women actually felt less confident in terms of what they knew about physical activity and would have preferred more advice from their midwife.

> *'there's no such thing as really showing you or describing it you know, or making sure that you are doing it [PA], I think that could be discussed or checked a little bit more' (Participant 14: 30 weeks pregnant)*

Some women were active when they had "knowledge" of the health benefits (e.g. keeping muscles strong for labour). Furthermore, women expressed interest in attending pregnancy exercise classes; if they were provided with information on these classes in their area they would be more likely to attend.

> *'I think that would be a good idea [PA information & resources], like if you were given like numbers and sort of classes around that area at your clinic appointments for like types of yoga and stuff like that' (Participant 04; 28 weeks pregnant)*

Behavioural regulation and goals

In terms of "behavioural regulation" women's comments on technology suggested that action planning and self-monitoring would be an enabler to physical activity. When discussing technology, women explained that a 'pedometer' or 'step count' might help in terms of motivation and to monitor current levels of physical activity.

> *'If there was definitely some sort of measurement like a pedometer or something like that, just something that would flag where you are at and what your targets should be' (Participant 21; 26 weeks pregnant)*

Some women suggested setting "goals" as an enabler to physical activity, providing them with targets to accomplish.

> *'I am very goal driven, I would love that, if someone said ' you need to walk three miles this week and you need to do four laps of the pool and something else, you know you would hit your targets and you know then that even if they say that was helping you, that you are going a good job. You're doing something good anyway' (Participant 18; 14 weeks pregnant)*

Although women felt a pedometer or step count would help with motivation, other forms of technology did not have the same perceived benefit. Women disliked the idea of tracking physical activity (number of days, length of activity time) in a phone app if it was linked with the antenatal clinic. They felt like *'big brother'* would be watching or that it was a chance for their health care professionals to *'check up on me'* calling it an *'invasion of privacy'*. Furthermore some women felt that tracking physical activity would be a *'burden'* or like *'homework'* and that with their busy lifestyles they would just forget.

'I'm not actually that good of keeping track of anything really like that [PA] (laughs) I would try to write things down but I would just be so busy or I would forget and I wouldn't do it, so I wouldn't be a good user of those [pregnancy apps]' (Participant 13; 32 weeks pregnant)

Opportunity

Environmental context and resources

Women's opportunity to engage in physical activity in pregnancy was often hindered by work and family commitments. Even though they were motivated to be physically active, often constraints in the way of time and bad weather conditions justified not participating in physical activity.

'I suppose prior to the first pregnancy I could go from work to exercise and then come home. Whereas, now if I do that I don't see my son before he goes to bed. So I just can't fit it into my day to be honest, it's more challenging' (Participant 21; 26 weeks pregnant)

Some women identified a lack of financial means as well as a lack of targeted services specifically tailored for pregnancy as barriers to physical activity. Women suggested subsidised services as a solution to financial difficulties. Making services *'financially viable'* might encourage the use of a gym or exercise class's thus enabling physical activity.

'I mean I'm not going just because I have two kids I have a massive big mortgage and I actually can't afford the full membership to go swimming.......Free gym membership for pregnant woman for 9 months (laughs) that would be great, even I would go then (laughs)' (Participant 16; 38 weeks pregnant)

Social influences

A commonly reported enabler was that of "social influences" which included family and friends encouragement of physical activity. Women's partner or husbands were the most influencing factor (e.g. *'always pushing me to go for a walk','he would drag me out for a walk'*).

The women's husbands were not seen as a barrier to PA while other family members were.

'Put your feet up' that's what I get especially over the last four weeks, from my mother in law' (Participant 16; 38 weeks pregnant)

Women also expressed an interest in pregnancy physical activity classes giving mothers a chance to *'talk'* comparing it to a *'support group'*.

'...it would be that extra motivation [PA classes]. Get out and make friends and talk more, and enjoy the activity more' (Participant 04; 28 weeks pregnant)

Motivation

Social role and identity

A clear justification for not engaging in physical activity was the 'individual'. It was commonly reported that *'every woman is different'* and *'every pregnancy is different'* and it was up to that 'individual' whether or not they would make healthy choices or be physically active.

'I think it definitely depends on the individual, I think it depends on the pregnant mother whether they want to be healthy or not...' (Participant 01; gestation unknown)

Belief about capability

When considering "belief about capability" pregnancy was viewed as a time for change particularly for the benefit of the baby *'I just have to... be as healthy as I can be now, I mean it's all for the baby' (Participant 13; 32 weeks pregnant).* The foremost feelings that prevailed throughout the interviews were the sense of *'responsibility'* in providing the best for the baby in terms of healthy lifestyle behaviours.

'...every woman is different and every woman will take on board information differently [diet & PA]. *I think it is very important when you're pregnant, you need to just take responsibility like, and you do. (Participant 19; 27 weeks pregnant)*

Some women also described how they were changing behaviour to be healthy not only for the baby but for themselves.

'..when I came out of my doctor I knew I was going to do something that was going to help me and the baby and that my actions would make us healthier together ya know. (Participant 18; 14 weeks pregnant)

At the same time, pregnancy provided a reason to not make healthy changes (e.g. *'...like sure I'm pregnant. I'm going to be big anyway' (Participant 09; 39 weeks pregnant)).* Woman felt that pregnancy could be used as an *'excuse'* and that *'mind-set'* played a big part in whether or not you would make any changes. Some women stated they would have to have been physically active at the start of pregnancy in order to keep it up and that breaking bad habits in pregnancy is difficult.

> *'No I would have to have been doing it from the start [PA]. I wouldn't have picked it up half way through. I definitely would have had to have started at the beginning. I mean I told myself at the start, I actually wouldn't mind doing that [PA] and keeping it up but I just didn't and then I just stopped and sat and eat....it's hard to break that habit especially when you are pregnant as you do use it as an excuse' (Participant 02; gestation unknown)*

Intentions

Others reported being motivated when talking about after pregnancy and their implicit intentions to change (e.g *'I have it planned out in my head'*).

> *'I know I am not having any more and I tell myself afterwards I'll get back into it' (Participant 02; gestation unknown)*

> *'So I said right when this baby now is done...after I have recovered I'm going back to my [PA] classes' (Participant 05; 28 weeks pregnant)*

Emotion

In terms of "emotion", enablers to physical activity included feelings of *'guilt'* and *'concern'*.

> *'if I could get away with it [no PA], if I could I would definitely but I know I would feel pure guilty. I know I would have them [health care professionals] looking at me and I would feel fierce guilty' (Participant 18; 14 weeks pregnant)*

> *'...the first time round I could go for walks, I was taking care of my health and ya know, you kind of that bit worried the first time round, you make sure you are doing the best for the baby and yourself' (Participant 01; gestation unknown)*

A fear based on previous pregnancy outcomes was highlighted with women afraid to do anything in pregnancy due to previous miscarriage experiences.

> *'...from the moment I knew I was pregnant it has been terrifying for me. Because like I'm after having 3 miscarriages in 2 years it's not a nice thing to experience, I mean you're constantly waiting to see that heartbeat..' (Participant 05; 28 weeks pregnant)*

Discussion

The aim of this study was to systematically identify the barriers and enablers to physical activity for women who are overweight and obese in pregnancy using the TDF and COM-B model. A wide range of barriers and enablers were identified which influenced women's capability, motivation and opportunity to engage in physical activity with women providing more information about barriers than enablers.

In the current study, the most commonly reported barrier to physical activity during pregnancy was "knowledge". It was clear from the findings that women were unclear on what types of physical activity they could engage in while pregnant and whether physical activity was safe. This finding is similar to that of a qualitative study conducted in the US, in which pregnant women mentioned a lack of advice regarding physical activity [58]; the most information they received from their midwives was to 'carry on as usual' [59]. Perhaps this lack of information can explain why adherence to physical activity guidelines is so low particularly for pregnant women with a BMI >25 kg/m^2 (6.4%) [24]. Health care professionals are key to enhancing pregnant women's knowledge of being physical active and the benefits of being active in pregnancy [60]. Furthermore, many women received little or no advice on appropriate weight management in pregnancy. Service providers [61], similar to the women here, considered verbal advice offered to women on topics such as lifestyle and weight management to be inconsistent and unsupported by written information [62]. This is perhaps not surprising given the lack of Irish guidance regarding weight management in pregnancy [22]. However, despite this the women actually expressed little concern about weight gain.

"Physical skills" such as pregnancy-related symptoms (e.g. morning sickness/nausea/pelvic pain) were common barriers to physical activity. However, research has shown that being physical active in early pregnancy can reduce these symptoms [11, 12]. Thus this information may be a useful motivational strategy to encourage overweight and obese women to be active early on. Furthermore, high risk pregnancies were identified as a barrier, yet, research has indicated that in the case of risk factors for preeclampsia, exercise has been seen to promote maternal circulation, improve maternal fetal vascularity and boost the immune system of women [63]. For women with high risk pregnancies, physical activity is recommended with some restrictions; but there are currently no clear recommendations available [64], therefore, evidence based guidelines are required for health care professionals in order for them to guide women about safe activity in pregnancy given their health status. Another barrier reported by the women was tiredness and a lack of energy due to being pregnant, work and family commitments. This is consistent with previous literature, feeling tired or having no energy are the most commonly reported reasons for not being active [58, 65–67].

The women identified "social influences" indicating the relative importance of advice received from family and friends in initiating physical activity behaviour. Also, the women enjoyed meeting other pregnant women and expressed interest in physical activity classes tailored for pregnancy. Healthcare professionals need to take a holistic approach to care, taking into consideration the women's social support network and influences to include their partners in group pregnancy sessions. Action planning and goal setting were identified by the women as a means of motivation and that pedometers and step counts could help with self-monitoring. A review, examining the use of pedometers to increase physical activity and improve health, concluded that pedometers were associated with significant increases in physical activity in an adult population [68]. Furthermore, in a study with pregnant women the pedometer was acceptable to the women [25]. Thus, future interventions should include some component of self-monitoring in order to improve physical activity levels in overweight and obese pregnant women.

Analysis using the TDF provided a detailed understanding of the barriers and enablers to physical activity for pregnant women and the refinement of the findings into the COM-B model has set the stage for developing a theory and evidence based intervention to increase physical activity levels in overweight and obese pregnant women. Using these frameworks added substantial strength to this study because it is composed of theoretically derived domains based on a comprehensive list of behavioural theories. This will help to identify potentially relevant domains and to select a set of relevant theories to investigate the target behaviour in depth at a later stage. While the study has some clear strengths, there were some potential limitations. While the TDF provided a comprehensive framework for understanding types of enablers and barriers to physical activity among this population, at times it was difficult to categorise themes due to lack of clarity in the definitions of the theoretical domains. Where this happened, the best solution was determined through discussion with members of the research team (CF) and (SMH). An additional limitation was the sampling frame for the study; all women were recruited through a public clinic in one maternity hospital setting potentially limiting diversity in study findings. Furthermore, even though this ethnically diverse sample of pregnant women shared similar views regarding physical activity, research is warranted to assess racial or cultural differences in overweight and obese pregnant women.

Conclusion

This research provides an important overview of the behavioural factors enabling or inhibiting physical activity and has also identified a system of behaviours that may be relevant in order to increase physical activity levels amongst overweight and obese pregnant women. Using the TDF and COM-B model is a theoretical starting point for understanding behaviour within specific contexts and to make a 'behavioural diagnosis' of what needs to change to alter behaviour. The COM-B model forms the hub of the Behaviour Change Wheel (BCW) which provides a systematic and transparent way to conduct a behavioural assessment, identify the target behaviour, select intervention functions and to develop theory based intervention strategies [45]. The findings suggest a lack of knowledge around safe types of physical activity in pregnancy and awareness of the potential benefits for mother and baby. Interventions which provide continuing support from health care professionals and involve partners and family members are potential approaches to consider for interventions in pregnancy. In future research, we will use the behaviour change wheel to identify intervention functions to systematically develop a lifestyle intervention to increase physical activity levels for overweight and obese pregnant women. Developing an antenatal intervention that targets these salient barriers to physical activity will have greater potential to change behaviour.

Additional file

Additional file 1 Table S1. Coding frame: barriers and enablers. (DOCX 38 kb)

Abbreviations

BCW: Behaviour Change Wheel; COM-B: Capability, opportunity and motivation-behaviour; PW: Pregnant woman; TDF: Theoretical Domains Framework

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Availability of data and materials

All data generated and/or analysed during this study are included in this article [Additional file 1].

Authors' contributions

CF, SMH, PMK and MB conceived and designed the study. CF and SMH developed the topic guide and study protocol. LCK and MOR facilitated access to pregnant women for recruitment to the study. CF and AEA facilitated and transcribed the interviews. CF and SMH coded the transcripts and developed and refined the themes. MB provided TDF and COM-B model expertise. CF wrote the first draft of the paper. All other authors (EC and FMA) contributed to successive drafts and the revising of the manuscript. All authors (CF, SMH, AEA, EC, MOR, LCK, FMA, PMK and MB) read and approved the final manuscript.

Ethics approval and consent to participate
Ethical approval was obtained from the University College Cork Clinical Research Ethics Committee of the Cork Teaching Hospital (ref: ECM 4 (y) 06/01/15). Written informed consent was obtained from all participants.

Consent for publication
Consent for publication was obtained from all participants.

Competing interests
The authors declare that they have no competing interests.

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Author details
[1]Health Behaviour Change Research Group, School of Psychology, National University of Ireland, Galway, Ireland. [2]School of Public Health, University College Cork, Cork, Ireland. [3]Department of Nutrition & Dietetics, South Infirmary Victoria University Hospital, Cork, Ireland. [4]Department Obstetrics and Gynaecology, University College Cork, Cork, Ireland. [5]Department of Women's and Children's Health, Faculty of Health and Life Sciences, University of Liverpool, Liverpool, UK. [6]UCD Perinatal Research Centre, School of Medicine, University College Dublin, National Maternity Hospital, Dublin, Ireland.

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BMJ Open

Exploring obstetricians', midwives' and general practitioners' approach to weight management in pregnant women with a BMI ≥25 kg/m^2: a qualitative study

Caragh Flannery,[1,2] Sheena McHugh,[2] Louise C Kenny,[3] Mairead N O'Riordan,[4] Fionnuala M McAuliffe,[5] Colin Bradley,[6] Patricia M Kearney,[2] Molly Byrne[1]

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For numbered affiliations see end of article.

Correspondence to
Ms Caragh Flannery;
cflannery@ucc.ie

ABSTRACT

Objective The aim of this study was to explore healthcare professionals' (HCPs) beliefs and attitudes towards weight management for pregnant women with a body mass index (BMI) ≥25 kg/m^2.

Design Qualitative study.

Setting A public antenatal clinic in a large academic maternity hospital in Cork, Ireland, and general practice clinics in the same region.

Participants HCPs such as hospital-based midwives and consultant obstetricians and general practitioners (GPs).

Method Semistructured interviews were conducted with a purposive sample of hospital-based HCPs and a sample of GPs working in the same region. Interviews were recorded, transcribed and thematically analysed using NVivo software.

Results Seventeen HCPs were interviewed (hospital based=10; GPs=7). Four themes identified the complexity of weight management in pregnancy and the challenges HCPs faced when trying to balance the medical and psychosocial needs of the women. HCPs acknowledged weight as a sensitive conversation topic, leading to a '*softly-softly approach*' to weight management. HCPs tried to strike a balance between being woman centred and empathetic and medicalising the conversation. HCPs described '*doing what you can with what you have*' and *shifting the focus to managing obstetric complications.* Furthermore, there were *unclear roles and responsibilities* in terms of weight management.

Conclusion HCPs need to have standardised approaches and evidence-based guidelines that support the consistent monitoring and management of weight during pregnancy.

Strengths and limitations of this study

- The inductive approach used in this qualitative study revealed the nuances and tensions involved in the management of overweight and obese pregnant women.
- The recruitment healthcare professionals (HCPs) across settings, including hospital-based HCPs and general practitioners with a range of experiences, is a further strength of this study.
- Most of the HCPs were recruited from a limited geographical area, and their perceptions and approach to weight management for overweight and obese pregnant women may not reflect those of HCPs working elsewhere.
- Variation in interview length occurred due to constraints and demands on participants' time.

INTRODUCTION

The prevalence of overweight and obesity during pregnancy is increasing.[1] Although some weight gain is to be expected during pregnancy, many women appear at their first antenatal appointment with a body mass index (BMI) ≥25 kg/m^2 representing a significant and increasing problem faced by healthcare professionals (HCPs) in obstetric practices.[1 2] Recent studies, in Ireland, reported that between 19% and 25% of women were categorised as overweight or obese in the first trimester[3] or at their first antenatal visit.[4] Furthermore, obesity in women was most widespread in high-income countries with a prevalence of 25% in the UK and 34% in the USA.[5] In Europe, the prevalence of overweight and obesity among pregnant women ranged between 33% and 50%[6]

Overweight is defined as BMI ≥25 kg/m^2, and obesity is defined as a BMI≥30 kg/m^2, which is assessed at the first antenatal consultation.[7] Gestational weight gain (GWG) is the total weight gained during pregnancy, with the largest weight gains generally occurring in the second and third trimester.[7 8] The Institute of Medicine (IOM) recommends different GWG for each BMI category.[7 9] These guidelines are individualised to prepregnancy BMI and are based on evidence of weight gain patterns in pregnancy and on health outcomes for mother and baby. A recent review that compared national GWG guidelines and energy intake recommendations found that 31% of countries were adopting these GWG guidelines.[10] Furthermore, after two different searches of available guidelines, the authors of the review found no GWG guidelines or recommendations available for Ireland.[10]

Problems associated with obesity during pregnancy include an increased risk of hypertensive disorders, higher rates of caesarean section and preterm delivery.[11] Moreover, excessive GWG in pregnancy increases the risk of developing gestational diabetes mellitus (GDM) and is a strong risk factor of long-term obesity.[12–14] Obesity also presents a greater risk of perinatal complication such as macrosomia.[15] Recent literature reviews have identified diet and lifestyle interventions as a means of reducing the risk of GWG, GDM and postnatal weight retention.[16–18] However, due to the poor quality of these studies and heterogeneity in the intervention designs, the results should be interpreted with caution and uncertainty persists around their effectiveness.[19]

While the delivery of antenatal care is different in many countries, a number of HCPs, including hospital-based HCPs (such as midwives and obstetricians) and general practitioners (GPs) provide care throughout pregnancy.[20] In Ireland, antenatal care is shared between hospital-based HCPs and GPs.[21] Pregnancy has been identified as a 'teachable moment' where woman's health motivations could be harnessed for long-term behaviour change and wider public health benefits beyond pregnancy, given women's vital role in supporting healthy lifestyles in the wider family unit.[22] The regular interactions between HCPs and women during pregnancy provide opportunities to support women to achieve positive lifestyle changes, particularly in terms of weight management.[23 24] While these HCPs have been identified as vital contributors to the antenatal services, in Ireland, little is known about the ways in which such professionals engage with overweight and obese pregnant women. HCPs have key opportunities to influence lifestyle and weight management in this shared care arena that are not currently fully availed of.[25 26]

Few studies in Ireland focus on the approach taken by HCPs regarding antenatal lifestyle advice and weight management.[27–29] Little is known about the use of guidelines in clinical practice and whether HCPs address the needs of overweight and obese pregnant women. A survey among obstetrics and trainee doctors in the USA found little knowledge of the revised IOM guidelines for appropriate GWG.[30] Over half of those surveyed were not aware of the new guidelines and less than 10% selected the correct BMI ranges or the correct GWG ranges. Previous qualitative studies have highlighted a number of barriers to weight management for HCPs including communication difficulties between HCPs and patient,[31] lack of confidence and training to provide weight advice[32] and a lack of resources within antenatal care.[33] Understanding the ways in which HCPs currently manage maternal obesity in an Irish context is necessary to inform the development of antenatal lifestyle interventions. Therefore, the aim of this study was to explore HCPs beliefs and attitudes towards weight management and their approach to working with overweight and obese pregnant women at a large academic maternity hospital in Cork, Ireland, and primary care settings in the same region.

METHODS

Study design

A qualitative study was conducted to understand HCPs experiences of weight management for both overweight and obese pregnant women.

Sampling and recruitment

Hospital-based HCPs were purposively sampled and identified at Grand Rounds from a public antenatal clinic in a large academic maternity hospital, Cork University Maternity Hospital (CUMH), Ireland. CUMH is a large academic maternity hospital in the south of Ireland where approximately 6657 new obstetrics patients entered in 2015.[34] Hospital-based HCPs included midwives and consultant obstetricians who provide care for women either during pregnancy, labour and birth or in the postnatal period. GPs in the Cork-Kerry region were identified using a GP list provided by the Department of General Practice, University College Cork, which included GP names and contact details. GPs were purposively sample based on gender and location of practice (urban/rural). GPs were recruited from single or group practices serving both public and private patients. HCPs were eligible if they were engaged in clinical practice during the time of the study and regularly consulted with pregnant women with a BMI $\geq$25 kg/m^2. HCPs were provided with an invitation letter and study information sheet and were informed that CF was conducting this research as part of her PhD work. Follow-up phone calls were made to determine if they were interested in participating.

Interview process

Face-to-face semistructured interviews were carried out by a single trained qualitative researcher (CF) at the hospital antenatal clinic or in the primary care setting between January and July 2016. Written informed consent was obtained from all HCPs prior to the interview. The topic guide was developed based on previous literature.[11 18 35 36] Key areas for discussion included addressing weight, lifestyle advice and resources and supports available (online supplementary file 1). The topic guide and interview process were piloted by interviewing two HCPs (a midwife working in Australia and a nurse no longer involved in clinical practice). Following this, refinements were made to the prompts used to ensure the interview was designed to capture HCPs experiences. Pilot interviews were not included in the final sample.

Patient and public involvement

As the interviews focused on HCPs beliefs and attitudes, patients were not directly involved in the design or administration of this research.

Table 1 Profile characteristics of HCPs (n=17)

	Male	Female
Occupation		
Midwife*	–	4
Senior house officer	–	1
Consultant obstetrician†	2	3
General practitioners	3	4
Location		
Cork	4	12
Kerry	1	–

*Midwife working in diabetic clinic (n=1); labour ward (n=1); outpatient department (n=2).
†Obstetrician's working in obstetrics with subspecialist interests such as maternal medicine, high-risk pregnancies, fetal medicine and complicated pregnancies (n=4) and gynaecology (n=1).
HCP, healthcare professionals.

Data analysis

Interviews were audio-recorded and transcribed verbatim. NVivo software was used to facilitate data analysis. Thematic analysis as described by Braun and Clarke[37] was used to analyse the data.[37] An inductive approach was used where transcripts were read and open-coded. These codes were grouped according to HCPs beliefs and attitudes, their approach to weight management and the reasons for this approach. Codes and categories were discussed, and subthemes were synthesised and organised to develop broader themes (CF and SMH). The data were analysed independently by one researcher (CF) with a subset of the transcripts dual coded (CF and SMH). To ensure the consistency of the findings, an audit trail was kept for transparency in the analysis. Hospital-based HCPs and GPs were reported as HCPs when similar views and attitudes were expressed. Differences between hospital-based HCPs and GPs were also recorded. The Consolidated criteria for Reporting Qualitative research statement was used to inform reporting of the findings (online supplementary file 2).

RESULTS

Thirty-six HCPs were invited; 17 participated (hospital based: n=10) and (GPs: n=7). The 17 interviews were analysed chronologically. With no new themes emerging, it was agreed that no more interviews were required. Table 1 provides details of the participants' characteristics including gender, occupation and location of practice. The interviews for hospital-based HCPs ranged from 23 min to 50 min in duration and GP interviews ranged from 14 min to 35 min.

Four major themes were identified that relate to HCPs attitudes and approaches to weight management: the '*softly-softly*' *approach to weight management*; '*doing what you can with what you have*', *shifting the focus to* the *management of obstetric complications* and *unclear roles and responsibilities for lifestyle advice*. Together these four themes reflect the complexity of weight management and how hospital-based HCPs and GPs discuss and approach weight management. Furthermore, HCPs describe the constraints within the system and highlight their attitudes to weight during pregnancy. Hospital-based HCPs and GPs shared similar views in terms of weight management, with differences emerging on issues such as weighing practices and concerns about who is ultimately responsible for the management of overweight and obese pregnant women. The themes are presented in figure 1.

The 'softly-softly' approach to weight management

Hospital-based HCPs and GPs identified the tension between attitudes towards weight at a population and individual level. At the population level, concerns were clear about the dramatic increase in maternal obesity and the attitude that '*being overweight is fine…people look at themselves and say, "Well, I'm just the same size as her." or "I'm thinner than her", therefore, I'm not overweight*' (Obstetrician 03). Furthermore, socialisation and family norms have resulted in unhealthy learnt behaviours and an environment in which obesity is now acceptable; '*we're normalising obesity, it's not perceived as a problem*' (GP 05). Despite this, at an individual level when managing maternal obesity, HCPs recognised the presence of stigma relating to weight and obesity. As a result, a '*softly-softly*' *approach to weight management* among overweight and obese pregnant women was adopted.

> … [W]e have a very softly-softly approach to obesity and overeating and over nourishment… (Obstetrician 07)

This cautious and diplomatic approach involved trying to strike a balance between being empathetic towards the women, medicalising the issue and acknowledging their duty as HCPs to inform the woman about the risks associated with overweight and obesity. This approach was used to raise and address the topic of weight throughout pregnancy.

The approach depended on how the women reacted to initial attempts to discuss weight and thus varied across women. In participants' experience, most women reacted negatively to the topic of weight and obesity in pregnancy; they disengage, the shutters come down, they can get a bit defensive or dismissive of it and thus it is not a two-way interaction.

Hospital-based HCPs and GPs were conscious of the patient experience and that their professional role required them to be sensitive, non-judging, encouraging, motivating and to act as a counsellor for each of their overweight patients. They were concerned about using the right language so as not to cause offence, anger or upset and they acknowledged that you cannot use the word '*fat*'. However, in some cases, HCPs highlighted the need to be upfront and blunt to get the message across. Hospital-based HCPs also recognised the need to be clear, to state the facts and to be honest with the woman

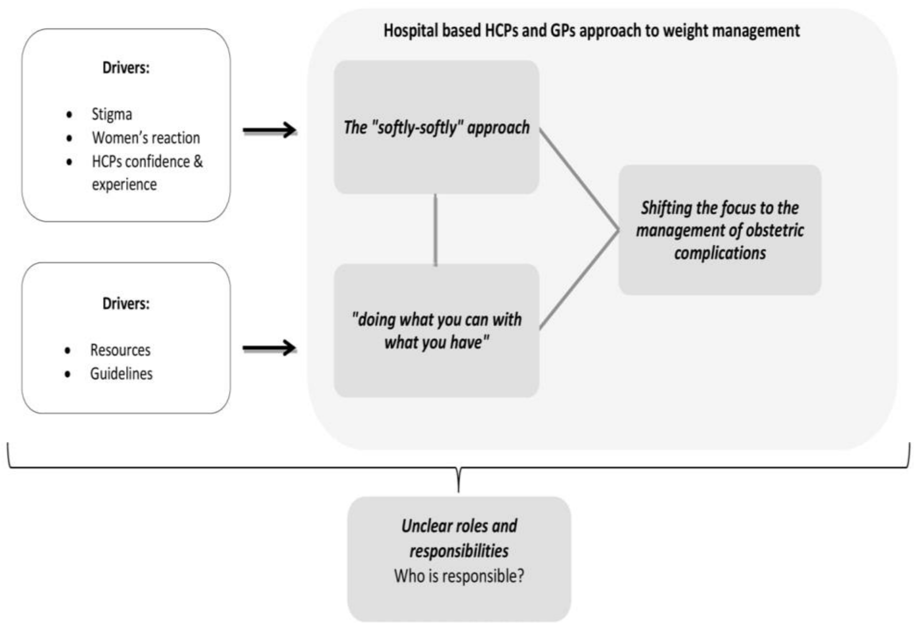

Figure 1 Drivers and approach to weight management for overweight and obese pregnant women. GPs, general practitioners; HCPs, healthcare professionals.

as it is their responsibility to help the woman manage her weight.

> No, I think we need to find a way of getting that message across and I think part of that is just normalising it…we've got to normalise chatting about weight…. I've tried a whole range of different ways and sometimes it's regarded as confrontational and I can feel that they're looking at me thinking, 'Well, I don't like that doctor.' It's not that I'm trying to make her feel bad, I want to point this out and I try and medicalise it and say, 'Well, you know your body mass index is over 30, that means you're obese, that puts you at risk of high blood pressure, diabetes. (Obstetrician 03)

Broaching the subject of weight

Hospital HCPs and GPs felt the need to adopt a '*softly-softly*' approach in relation to the topic of weight compared with a more direct approach they might take with issues such as blood pressure. Raising the subject of weight was influenced by confidence and experience. Some HCPs considered themselves experienced enough to discuss '*uncomfortable truths*' about obesity such as potential complications. Others found it difficult to broach the subject; in particular, hospital-based HCPs such as junior midwives found raising the topic awkward. To facilitate the conversation, more experienced hospital-based HCPs drew on their personal weight issues to relate to the women.

> … I'm not the skinniest person in the world. I think it's easier when you can say, 'Look, we all have our challenges and you've got to work hard at it'. (Obstetrician 06)

More detached approaches were also described, with hospital-based HCPs using tools such as a BMI categorisation tool to frame the conversation because using BMI '*isn't as upsetting to somebody as if you said, You're fat*' (midwife 01). Furthermore, because of women's weight, difficulties were often experienced when palpating a woman's abdomen and conducting fetal scans, offering an opportune situation to raise the issue and to discuss the potential complications.

> I actually say it straight out to them when I am scanning, look unfortunately you carry the extra adipose tissue I am finding it difficult, there is too much fat around you abdomen which you need to watch. I would say that straight-out… (Midwife 01)

All HCPs acknowledged that conversations about weight occur frequently throughout pregnancy as they have continuous contact with pregnant women. However, these discussions were quick conversations due to large caseloads, time and due to the number of topics that needed to be addressed within the consultations: '*it would be a couple of minutes given to a discussion about their weight and the problems with it…*' (obstetrician 09).

'Doing what you can with what you have' to support the management of overweight and obesity

In the current '*obesogenic environment*', HCPs faced numerous challenges when supporting women to manage their weight. It was identified that the woman's health, their level of risk in pregnancy and scarce resources dictated what HCPs could do to support women's weight management efforts.

Hospital-based HCPs were adapting the evidence to deal with large caseloads of women with high BMIs '*… so we don't talk about weight to the women who are overweight, we save that for the women who are obese…*' (obstetrician 03). Due to scarce resources, priority was given to the obese women rather than overweight women: '*we have far too many women with BMIs in the 40s or even in the 50s in whom we focus our limited resources*' (obstetrician 03); therefore, women with a BMI ≥25 kg/m^2 '*doesn't raise as much of a red flag*'. Limited dietetic services within the hospital were discussed as an example of the inadequate resources, with this service only offered to those with a diagnosis of GDM. This reflected the '*doing what you can with what you have*' approach as hospital-based HCPs could do more for these pregnant women. Hospital-based HCPs emphasised that this service needed to reach all women, particularly overweight and obese women (without GDM) who could benefit from that type of intervention. Also, access to dietetics influenced GPs' management of weight; long waiting times for referrals meant that they lost that window to intervene with the woman.

Most hospital-based HCPs did not have any '*specific written guidelines*' to follow, while others described using and applying varying ranges of weight gain in pregnancy. A BMI ≥30 kg/m^2 was so common that it was considered a low priority for services, management and advice rendering some guidelines '*inadequate*'.

> I think the guidelines and the public health policies that are out there are inadequate….. they're certainly not permeating into a lot of healthcare professionals' consciousness and I think many doctors don't regard a BMI of 30 [as priority] because it's becoming more and more common. (Obstetrician 07)

The '*doing what you can with what you have*' approach to weight management was also reflected in weighing practices and attitudes towards weighing. Weighing practices varied among the HCPs, and there were divergent attitudes towards its usefulness and appropriateness. GPs highlighted that the evidence and guidelines no longer recommend weight as a '*clinical indicator*'.

> … [I]t was stopped being done as routine because it wasn't correlating with health outcomes. That's my understanding of it, but I certainly would be interested to see if there are new guidelines about it. So if it is significant, I think it should be included in the chart… (GP 03)

However, hospital-based HCPs such as midwives were keeping track of women's weight, particularly at the booking visit and again at 28 weeks. Weight and BMI was used in the hospital to refer women for anaesthetic assessment to determine the woman's '*anaesthetic risk*'.

Shifting the focus to the management of obstetric complications

The risk of obstetric complications at any stage in pregnancy takes precedent over efforts to manage weight with hospital-based HCPs acknowledging '*it's too late [to manage weight] at that stage*'. For hospital-based HCPs, weight management was superseded when obstetric complications arose. At this point, the woman's complications required obstetric care, shifting the focus to the immediate health of the woman and baby.

> If they develop hypertension, I talk about hypertension and the treatment of. It's very difficult at that point, they're now hypertensive, the baby's at risk of growth restriction, they're at risk of early delivery, we need to get their blood pressure under control, take care of the maternal problems and make sure the foetus is okay. It's too late at that stage to start going, 'Oh well, you have this now because you're fat.' no, it's too late. (Obstetrician 03)

Unclear roles and responsibilities for lifestyle advice

In the context of shared maternity care, HCPs highlighted the challenge of providing continuity of care and questioned who is ultimately responsible for managing weight. It was difficult for hospital-based HCPs to provide continuous weight management and advice as they had limited opportunity to follow-up with the same women. Therefore, responsibility of continuous care fell to the GPs. Hospital-based HCPs suggested the GP would have a better family picture and would have the opportunity to engage with these women on numerous occasions preconception and throughout pregnancy.

> I think there GP should be one that keeps an eye on it [weight], he is the continuous person that's with them. (Midwife 01)

In contrast, GPs tended to put onus on the hospital-based HCPs, reporting '*Oh well look, the hospital will take care of that*' (GP 05) or we are very stretched in general practice. Even though both hospital-based HCPs and GPs are taking part in shared antenatal care, GPs felt there was little communication between primary and secondary care, and more clarity was required around role responsibilities and expectations within the shared care setting. This would ensure that weight-related conversations were consistent and reliable.

DISCUSSION

This qualitative study demonstrates the challenges surrounding weight management during pregnancy for overweight and obese women from the perspective of hospital-based HCPs and GPs with more concerns for women in the higher BMI categories. Four major themes were identified: the '*softly-softly*' approach, '*doing what you can with what you have*', *shifting the focus to* the *management of obstetric complications* and *unclear roles and responsibilities for lifestyle advice*. These themes reflect how HCPs discuss and manage weight, and the challenges they face when trying to balance the medical and psychosocial needs of the women.

The '*softly-softly*' approach is defined as cautious and patient and avoids direct action or force that reflects HCPs' accounts of their approach to providing care for overweight and obese pregnant women. Similar to this study, previous research identified an increased acceptance of obesity within the population[26 38–40] with fewer people now defining themselves as overweight and obese and underestimating their weight status.[38 39 41] Furthermore, stigma in relation to obesity was also present in this study and in previous research with HCPs feeling the discomfort and awkwardness around weight conversations in pregnancy.[40] A lack of confidence and experience determined the approach used to broach the subject of weight, with younger midwives in particular finding the topic awkward. This is supported by existing literature, with junior HCPs having negative opinions about their skills for treating obese patients.[28 42 43] Hospital-based HCPs and GPs in this study were aware that weight needs to be addressed with care to avoid upsetting the women. Similarly, in other studies, HCPs were concerned about victimising the women or jeopardising their relationship with the women when raising the subject of weight.[26 28 33] Midwives tried to broach the subject of weight by discussing their own weight loss journeys. In contrast, a study exploring the experiences of HCPs found that HCPs with high BMIs felt they were not in a position to address weight and therefore veered away from the conversation.[42] Standardised questions could be used with all pregnant women to reduce stigma associated with the conversation of weight and increase HCPs' confidence.[44] Experienced, well-informed HCPs need to share their training, knowledge and experience with more junior staff, including prompts and communication strategies, in order to improve addressing the subject of weight.[31] Scarce resources determined HCPs' approach to managing weight, particularly dietetic services that were consequently limited to women with GDM. Similarly, previous research identified limited resources available within maternity units as a barrier to managing weight during pregnancy.[26 40] With a number of diet and physical activity interventions reducing GWG and GDM,[17 19 45] it is clear that services such as dietetics need to reach all women, particularly women with a BMI ≥25 kg/m^2. As revealed in this study, HCPs had different views on routine weighing practices. Previous research indicated that while there are benefits to routine weighing, various challenges such as existing resources and time constraints need to be addressed in order to successfully implement the process of routine weighing of all women at every antenatal visit.[46] Furthermore, advice regarding the amount of weight to gain in pregnancy varied. This is perhaps not surprising as there is no formal guidance for appropriate GWG in Ireland. Previous research has demonstrated an evidence–practice gap relating to the provisional of clinical care of overweight and obese pregnant women.[47] Similarly, in the UK, HCPs were unsure about appropriate GWG in pregnancy.[27] Evidence suggests that women who are not advised about appropriate GWG are more likely to gain outside the recommended ranges.[48] Therefore, further research and national guidance is needed to address divergent opinions about the benefits of weighting practices and lack of clarity on appropriate GWG to support standardised shared antenatal care.

Strengths and limitations

The inductive approach used in this qualitative study revealed the nuances and tensions involved in the management of overweight and obese pregnant women. The recruitment of a diverse sample of HCPs across settings, including hospital-based HCPs and GPs with a range of experiences and specialities is a further strength of this study. Most of the HCPs were recruited from a limited geographical area and their perceptions and approach to weight management may not reflect those of HCPs working elsewhere. Variation in interview length occurred due to constraints and demands on participants' time.

Practice implications

Hospital-based HCPs and GPs are aware of the stigma around the topic of weight, particularly for women with a BMI ≥25 kg/m^2. As part of encouraging healthy lifestyle choices, HCPs need to normalise the conversation around weight. Other health behaviours such as smoking and alcohol are considered more acceptable and easier to discuss[26]; therefore, HCPs need to approach weight conversations in a similar manner. Training, education and skill development is required for HCPs to care effectively for these women. Lack of continuity of care undermines the consistency of weight management conversations and advice. Creating multidisciplinary teams or networks within the shared antenatal care setting would enhance and encourage knowledge sharing between HCPs allowing for effective communication between primary and secondary care. Furthermore, standardised approaches to weight management are needed and, where possible, HCPs need to follow women during pregnancy to build rapport and ensure consistent information throughout. To address the sensitive nature of weight conversations, the most important question for HCPs is to ask how a patient feels about their weight in pregnancy. Negative reactions will alert HCPs that additional support may be required. Additionally, motivational interviewing could be used; this has been previously identified as an effective strategy when approaching sensitive issues such as obesity.[49]

CONCLUSION

Building rapport is necessary to deal with the sensitive nature of weight, which requires consistent contact and guidance from HCPs. Roles and responsibilities for weight management within shared care needs to be clearer in this '*obesogenic environment*'. By ensuring hospital-based HCPs and GPS have the confidence, knowledge and opportunity to discuss weight and lifestyle factors with pregnant women, the women in turn may initiate or maintain healthy behaviours during pregnancy. Within shared care, evidence-based guidelines that support the consistent monitoring and management of weight during pregnancy could improve care and outcomes for these women.

Author affiliations
[1]Health Behaviour Change Research Group, School of Psychology, National University of Ireland, Galway, Ireland
[2]School of Public Health, University College Cork, Cork, Ireland
[3]Department of Women's and Children's Health, University of Liverpool School of Life Sciences, Liverpool, UK
[4]Department of Obstetrics and Gynaecology, University College Cork, Cork, Ireland
[5]UCD Perinatal Research Centre, School of Medicine, National Maternity Hospital, University College Dublin, Dublin, Ireland
[6]Department of General Practice, University College Cork, Cork, Ireland

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Competing interests None declared.

Patient consent Not required.

Ethics approval CF confirms that all patient identifiers have been removed so the patients described are not identifiable and cannot be identified through the details of the story. Ethical approval was obtained from the University College Cork Clinical Research Ethics Committee of the Cork Teaching Hospital (ref: ECM 4 (y) 06/01/15). Written informed consent was obtained from all participants.

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Investigating the Perceived Benefits, Barriers and Beliefs towards Physical Activity in Pregnancy among Women with Gestational Diabetes Mellitus

C Hurst[1], C Flannery[2], M Byrne[2], P M. Kearney[3], F Dunne[2], M O'Riordan[3], J C. Walsh[2].*

[1]University of Limerick,
[2]National University of Ireland, Galway,
[3]University College Cork

Abstract

Gestational Diabetes Mellitus (GDM) is a growing concern and poses serious health risks to both mother and child[1]. The current study explores the psychological determinants of exercise behaviour in a sample of pregnant women with GDM. A cross-sectional survey design was employed to examine exercise behaviour, illness perceptions, perceived barriers and benefits, exercise beliefs, and exercise self-efficacy using validated questionnaires. A sample of 46 pregnant women was recruited from University College Hospital Galway, Letterkenny General Hospital, Cork University Hospital and Mayo General Hospital in Castlebar. Participant's varied; age (22-44 years), body mass index (19-41). High mean scores for Personal Control (24.5) and Treatment Control (30.2) subscales indicated strongly held positive beliefs in relation to controllability of the illness. Total MET-min/week score was not related to any psychological variables. Analysis of the IPQ-R data revealed 'diet' (n=37, 80.4%) as the most referred to cause of diabetes. Exercise belief data identified "managing weight gain" (n= 21, 45.7%), and "losing baby weight" (n= 31, 67.4%) as the most frequent beliefs for engaging in physical activity during pregnancy and post pregnancy. Further research on the psychological determinants of physical activity behaviour among this population group is needed in order to create successful intervention strategies.

Introduction

Gestational Diabetes Mellitus (GDM) is increasing in prevalence, with rising levels of maternal overweight and obesity a major contributor[2]. GDM increases the likelihood of caesarean delivery, macrosomia, neonatal abnormalities and birth trauma[3]. The future health of the mother and baby are also at an increased risk of being compromised following diabetes in pregnancy, with the risk of developing type-2 diabetes seven times greater than in normal glycemic pregnancies[2]. Children born to women with gestational diabetes are also at an increased risk of developing respiratory distress syndrome, jaundice, childhood obesity and metabolic syndrome when compared with children of non-diabetic women[4]. Research has found that being physically active prior to becoming pregnant as well as during pregnancy and postpartum, has the potential to reduce the risk of progression from gestational diabetes to type 2-diabetes[5].

In the past, it has been speculated that exercise during pregnancy could lead to adverse events such as overheating, impaired delivery of oxygen and nutrients to the foetus and premature labour[6]. However, evidence to support these assertions is lacking and research indicates that exercise in pregnancy is in fact safe[7]. Physical activity reduces the risk of pregnancy complications such as preeclampsia, preterm delivery and gestational diabetes along with reducing discomfort, increasing fitness for labour and increasing the likelihood of vaginal delivery[8,9]. The American College of Obstetricians and Gynaecologists (ACOG) recommend 30 minutes of moderate intensity physical activity for pregnant women without obstetrical complications[10]. However, despite this information encouraging an active lifestyle during pregnancy remains a challenge. Regarding physical activity levels, the United States reported that only 15.8% of women engaged in exercise during pregnancy at the recommended level, while 34% of pregnant women had not engaged in any moderate or

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vigorous activity[11]. Similarly, low levels of physical activity (21.5%) were found in an Irish cohort of pregnant women[12] and in a sample of Danish pregnant women, moderate-to-heavy activities decreased over the three trimesters of pregnancy[13]. Furthermore the results from a study conducted in Brazil showed alarmingly low rates of physical activity, with only 4.7% of pregnant women being active[14].

Pregnancy is a time when health behaviours such as physical activity can be challenged in order to improve not only the mother's health but the health of the baby[15]. The likelihood of someone making a substantial behaviour change is dependent on a host of factors such as; beliefs, values, perceived barriers, and exercise self-efficacy[16]. The development and future success of exercise interventions among pregnant women with GDM hinges on having an accurate insight into these psychological determinants. There is a need to understand the facilitators and barriers to exercise in pregnancy and to understand the relationships between psychological predictors in order to develop effective interventions and strategies[1,17]. It is evident that prior to promoting exercise to this particular group of women, the specific exercise determinants need to be examined. Therefore the aim of this study is to explore the psychological determinants of exercise behaviour in pregnancy in women with GDM.

Method

A cross-sectional study was conducted with a sample of pregnant women with GDM (N=46) in June 2014. Ethical approval was obtained from the National University of Ireland, Galway Research Ethics Committee and the University College Hospital Galway ethics committee. Participants were pregnant women diagnosed with GDM who were attending the diabetes clinics in four participating hospitals. Exclusion criteria included not having sufficient level of English language to complete the questionnaire, and the presence of any co-morbidity or pre-existing condition other than diabetes. Participants were recruited from the diabetes clinics and maternity outpatients of four large hospitals. Women were approached and provided with information detailing the study aims. Those willing to participate were given the choice of completing the survey on site, or were given a stamped addressed envelope to post the completed survey back. Participation was voluntary, and women were free to withdraw at any point. Informed consent was obtained prior to the completion of the survey. Women attending the clinic on the days when the researcher was not present were sent the survey via post along with a stamped addressed envelope for its return. A total of 101 surveys were distributed, based on previous research in the area[6,16]. Basic demographic information was obtained including ethnicity, relationship status (single/married); education level (secondary/tertiary); employment status (employed/unemployed); parity (first pregnancy/two or more) height; weight; smoking (yes/no) and drinking behaviour (number of units). Body mass index was calculated using height and weight. A number of validated questionnaire were used including International Physical Activity Questionnaire (IPAQ) Long version, The Revised Illness Perception Questionnaire (IPQ-R) Diabetes Version, Health Value Scale (HVS), Exercise Benefits and Barriers Scale (EBBS), Exercise Belief Questionnaire (EBQ) Symons, Self-Efficacy for Exercise (SEE) Scale[18-23].

Analysis was conducted using IBM® SPSS® Statistics, Version 21. Associations between physical activity scores on the IPAQ and the psychological factors were explored using Chi-squared tests, Kruskal-Wallis, Mann–Whitney U and Pearson's correlation. Pearson's Product Moment Correlation Coefficient was conducted to examine the relationship between demographic variables and Total MET-min/week, or the Leisure-Time Physical Activity (LTPA). Kruskal-Wallis test was conducted between recruitment location and both Total MET-min/week and LTPA. Mann-Whitney U tests were conducted between physical activity and smoking behaviour, education level, and employment status.

Results

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Descriptive Statistics

Forty-seven questionnaires were returned with one incomplete survey excluded, thus 46 (45.5%) surveys were analysed. Participants ages ranged from 23 to 44 years (M=36.13, SD=4.05, N=38), with participant's BMI's ranging from 18.93 to 40.96 (M=29.77, SD=5.28, N=34). Descriptive characteristics are outlined in Table 1.

Table 1. Participant characteristics

Variable	N (%)
Relationship Status	
Single	4 (8.7)
Married/In committed relationship	42 (91.3)
Education Level	
Completed Secondary School	16 (34.8)
Tertiary Qualification	30 (65.2)
Employment Status	
Employed	37 (80.4)
Unemployed	9 (19.6)
Parity	
First Pregnancy	15 (32.6)
Second or more	31 (67.4)
Smoking Behaviour	
Yes	8 (17.4)
No	38 (82.6)
Alcohol Consumption	
None	35 (76.1)
<2 Units	9 (19.6)
3 - 8 Units	1 (2.2)
>8 Units	1 (2.2)

Characteristics of participants reporting physical activity

The analyses revealed no significant relationships between age and Total MET-min/week (r=0.06, p=0.75), BMI and Total MET-min/week (r=0.04, p=0.83), age and LTPA (r =0.05, p=0.77) or BMI and LTPA (r=-0.25, p=0.15). Recruitment, location and Total MET-min/week (χ^2=1.38, df=3, p=0.71) and LTPA (χ^2=5.7, df=3, p=0.13) found no significant differences between locations. No significant differences were found between the other demographic variables (alcohol consumption, and relationship status) on the physical activity scores. Smoking behaviour, education level, and employment status found no significant difference with the physical activity measures.

Correlation analysis between physical activity scores on the IPAQ and the psychological factors

Correlational analyses were conducted between both MET and LTPA physical activity scores, and each of the psychological measures; Health Value Scale, Exercise Benefits and Barriers Scale Total (EBBS), Benefits subscale, Barriers subscale, and the Self-Efficacy in Exercise Scale (SEE). Results revealed no significant correlations between any of the variables and Total MET-min/week scores. Significant results were found between the LTPA score, presented in table 2.

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Table 2. Summary of inter-correlations between IPAQ Leisure-Time Physical Activity Domain Score (LTPA) and Relevant Psychological Variables

Variable	1.	2.	3.	4.	5.	6.
1. LTPA	-					
2. HVS	.19	-				
3. EBBS Total	.42**	.40**	-			
4. SEE	.32*	.42**	.54*	-		
5. EBBS Barrier subscale	-.30*	-.51**	-.83**	.62**	-	
6. EBBS Benefit subscale	.43**	.32*	.96**	.42**	-.60**	-

Note. HVS= Health Value Scale, EBBS=Exercise Benefits and Barriers Scale, SEE= Self-Efficacy for Exercise Scale

*p<.05, **p<.01

The IPQ-R data, representing the participants' views about their illness, was analysed by comparing the mean scores on each of the seven subscales. The higher mean scores on the Personal Control and Treatment Control subscales indicated strongly held positive beliefs by participants in relation to the controllability of the illness. Lower mean scores were recorded for Illness Coherence, Consequences and Emotional Representations subscales, with both Timeline: acute/chronic and cyclical; subscales having the lowest mean scores. Means and standard deviations for each of the seven subscales are presented in Table 3.

Table 3. Means and Standard Deviations for IPQ-R Subscales

Subscale	M (SD)
Personal Control	24.48 (3.51)
Treatment Control	20.22 (2.35)
Illness Coherence	18.43 (3.30)
Consequences	16.02 (4.75)
Emotional Representations	15.22 (4.52)
Timeline (Acute/Chronic)	12.24 (4.150
Timeline (Cyclical)	10.98 (2.99)

In relation to the Causes subscale, four causes in particular were prominent in relation to the frequency of agreement from participants. The top cited cause was "Diet/Eating Habits" (80.4% agreement), followed by "Hereditary/It Runs in My Family" (63.0% agreement), "My Own Behaviour" (60.9% agreement) and "Ageing" (58.7% agreement). The remaining 14 causes listed were infrequently cited by participants in comparison to the above four causes.

From the Exercise Belief Questionnaire the most noticeable behavioural beliefs to engaging in physical activity during pregnancy was; "Managing weight gain" (45.65%), while "Losing baby weight" (67.39%) was the most frequent behavioural beliefs for engaging in physical activity post pregnancy (Table 4).

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Table 4. Behavioural beliefs to engaging in physical activity during pregnancy and post pregnancy

Exercise Belief Questionnaire (N=46)			% (n)*
Physical activity during pregnancy	Behavioural beliefs	Managing weight gain	45.64 (21)
		Manage diabetes/keep blood sugar down	36.96 (17)
		Keep fit	23.91 (11)
		Prepare body for labour	23.91 (11)
	Normative beliefs	Family	47.83 (22)
		Myself	28.26 (13)
		Baby	26.09 (12)
	Control beliefs	Pain/Discomfort	54.35 (25)
		Tiredness/Fatigue/No energy	39.13 (18)
Physical activity post pregnancy	Behavioural beliefs	Losing baby weight	67.39 (31)
		Getting back in shape/Improve fitness	32.61 (15)
		Relaxation/Reduce stress	32.61 (15)
	Normative beliefs	Family	50.00 (23)
		Baby/children	34.78 (16)
		Myself	23.91 (11)
	Control beliefs	Lack of time	39.13 (18)
		Tiredness/Fatigue/No energy	23.91 (11)
		Pain/Discomfort	19.57 (9)

*Results are presented as % of N=46

Discussion

This exploratory study describes physical activity scores among women with a diagnosis of GDM along with the psychological factors. Analysis of the data revealed that perceived benefits, barriers and exercise self-efficacy are significantly related to, and predict LTPA. Furthermore the Total MET-min/week score was not related to any of the psychological variables. Being physically active is important for any pregnant woman, however it may be more so, for women with GDM as they are at risk of type-2 diabetes later in life. Considering that approximately 40% of women affected by GDM may develop type-2 diabetes within four years[7], addressing this public health issue is vital. Studies have shown that increasing physical activity can potentially reduce the onset of diabetes progression from GDM[24] with physical activity in the early stages of pregnancy reducing the risk of GDM by 48%[25].

Results from the IPQ-R subscale indicate that diet was the most frequently cited cause, suggesting an awareness of control. If this awareness could be transferred into a positive change, through taking control of their dietary habits and being more physically active, women with GDM could vastly improve their outcomes. The specific barriers and benefits to exercise cited by participants from the Exercise Belief Questionnaire, are in line with those recorded in previous research. Lack of time, fatigue and being too tired were commonly reported barriers[11,16]. There is a need to address these barriers and discover ways for women to overcome them if they are to stand any chance of adopting and maintaining exercise behaviour.

The study has a few limitations. The IPAQ is a self-report measure and is subject to bias. The IPAQ requires participants to separate physical activity into domains and intensity which could be misleading. Secondly, having obtained only a 45.5% response rate of 46 participants results are not generalisable. Two importance factors were omitted from the survey; a record of pre-pregnancy physical activity, and gestational period. Throughout the course of a pregnancy, barriers, benefits and beliefs can shift. Having had a record of pre-pregnancy exercise levels would have added an extra dimension to the analysis. Future research should focus on motivators and facilitators to exercise, means of overcoming barriers and changing dysfunctional beliefs and perceptions. To achieve this successfully, a more holistic approach is necessary, where psychological constructs and cognitive strategies are discussed and explored. There is a huge potential for behavioural strategies such as goal-setting, along with the use of technology to influence these exercise determinants[1]. Further research is needed to identify which strategies might be successful in increasing physical activity behaviour among this population.

Conflict of interest
The authors declare that they have no competing interests.

Correspondence: Caragh Flannery, SPHeRE PhD Scholar, Health Behaviour Change Research Group/School of Psychology/Arts Millennium Building/NUI Galway/Ireland
Dept. Epidemiology & Public Health/University College Cork/Cork/Ireland
c.flannery13@nuigalway.ie / cflannery@ucc.ie

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