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Dietary intake and physical activity in severely obese pregnancy in Scotland

By:

Nor Azwani Mohd Shukri

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Abstract

Maternal obesity is associated with adverse effects for mothers and offspring. The primary aim of this thesis was to assess food intake and physical activity (PA) using validated self-administered questionnaires, and whether these were associated with gestational weight gain (GWG) and birthweight (BWT), in severely obese (body mass index, BMI≥40kg/m^2) compared with lean pregnant women (BMI 20-25kg/m^2). The secondary aims were to validate self-reports against food diary (FD) and accelerometry; to assess the prevalence of under or over-reporting of energy intake; and to carry out a pilot study to assess total energy expenditure, as well as self-reporting accuracy, by using doubly-labelled water (DLW) technique, in subgroups of participants.

Pregnant women were recruited from an ongoing study of severe obesity in pregnancy at the Royal Infirmary of Edinburgh, UK. Assessments were done in early (12-20 weeks) and late (28-32 weeks) pregnancy. A subgroup of women also completed questionnaires on appetite, general nutrition knowledge, and eating behaviours. All results were adjusted for age, parity, ethnic origin and deprivation category score.

Self-reported total energy intake was not significantly different between obese and lean during early (median 2,444 vs 2,312 kcal/day) and late (2,173 vs 2,354 kcal/day) pregnancy. However when validated with FD, the relative validity of the food frequency questionnaire was lower in obese compared to lean. Under-reporting of total energy intake was higher in obese compared to lean (49% vs 15%, *P<0.01*) through comparison of self-reported energy intake with estimated total energy expenditure, and this was supported by the DLW pilot study results. The DLW also showed possible over-reporting of PA by the obese group. Obese women reported significantly lower appetite than lean throughout pregnancy (*P<0.01*). They also had lower scores in general nutrition knowledge, but these were no longer significant after controlling for confounders. Obese women had significantly

higher scores of restrained and emotional eating behaviours than, and similar scores of external eating behaviours to, lean. Appetite, nutrition knowledge, restraint and emotional eating behaviours scores were not associated with food intake in either obese or lean. On the other hand, increased intakes of total calories and fats were influenced by increasing score of external eating behaviour in both groups. Obese women reported doing similar amounts of total PA but significantly less of vigorous and sports and exercise activities than lean (*P<0.05*). Accelerometry showed obese women had lower average activity counts/day, although they did have significantly greater energy expenditure in light-intensity activity than lean (*P<0.01*). Obese women had less GWG than lean (Mean ± SD, 5.3± 52 vs 10.8±3.7kg, *P<0.001*). Increased GWG was associated with increased self-reported total energy intake in lean, but this was not seen in obese. GWG was not associated with PA in either group. BWT was not significantly different between obese and lean (3,547±549g vs 3,567±516g). In lean, increased BWT was associated with increased energy intake and total PA. BWT in obese was not associated with diet but with increased with PA in early pregnancy.

In conclusion, self-reported methods were less reliable in assessment of diet and PA in severely obese compared to lean pregnant women. These exploratory studies found that obese women did not appear to have the same factors as lean women affecting GWG and BWT, though this may be complicated by the poor reliability of self-reports. Therefore, quantitative assessments such as measurement of serum micronutrient levels (to evaluate nutritional status), and accelerometry (to assess physical activity) may be necessary in this poorly understood population.

Content Page

CHAPTER 2

Methods and materials

CHAPTER 5

Misreporting of total energy intake

CHAPTER 6

Assessment of physical activity and validation of self-reported information using accelerometry

CHAPTER 7

Potential associations between diet/physical activity and gestational weight gain/birth weight

CHAPTER 8

Assessment of total energy expenditure and self-reporting accuracy using doubly-labelled water technique: A pilot study

CHAPTER 9

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Nor Azwani Mohd Shukri
October 2011

Declaration

This thesis is the original research of the author unless otherwise stated.

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This thesis has not been submitted previously at this or any other university for any other degree or professional qualification.

Signature:

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Nor Azwani Mohd Shukri

List of Abstracts arising from this thesis

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List of Abbreviations

AEE	Activity energy expenditure
AMC	Antenatal Metabolic Clinic
ANOVA	Analysis of variance
BMI	Basal metabolic rate
BMR	Basal metabolic rate
BWT	Birth weight
CMACE	Centre for Maternal and Child Health Enquiries
CNAQ	Council on Nutrition Appetite Questionnaire
DEBQ	Dutch Eating Behaviour Questionnaire
DEPCAT	Deprivation Category
DLW	Doubly-labelled water
EBIP	Energy Balance in Pregnancy
EER	Estimated energy requirement
EI	Energy intake
FAO	Food and Agriculture Organisation
FD	Food diary
FFQ	Food frequency questionnaire
GI	Glycemic index
GNKQ	General Nutrition Knowledge Questionnaire
GWG	Gestational weight gain
HADS	Hospital Anxiety and Depression Scale
HIP	Hormones and Inflammation in Pregnancy
IOM	Institute of Medicine
LGA	Large-for-age
MET	Metabolic equivalent

MUFA	Monounsaturated fatty acids
NDNS	National Diet and Nutrition Survey
NICE	National Institute for Health and Clinical Excellence
OECD	Organisation for Economic Co-operation and Development
PA	Physical activity
PAL	Physical activity level
PPAQ	Pregnancy Physical Activity Questionnaire
PUFA	Polyunsaturated fatty acids
RDA	Recommended dietary allowance
SCG-FFQ	Scottish Collaborative Group Food Frequency Questionnaire
SEATON	Study of Eczema and Asthma to Observe the Effect of Nutrition
SD	Standard deviation
SEM	Standard error mean
SFA	Saturated fatty acids
SGA	Small-for-age
SWLS	Satisfaction with Life Scale
TEE	Total energy expenditure
TEF	Thermic effect of food
UK	United Kingdom
UNU	United Nations University
WHO	World Health Organization

List of Tables

List of Figures

List of Appendices

CHAPTER 1

Introduction

Chapter 1

This thesis investigates diet and physical activity (PA), the modifiable factors that determine energy balance, and their potential effect on weight gain and birthweight (BWT) in pregnancy associated with severe obesity. This chapter will review the prevalence and complications of maternal obesity, as well as the factors that influence energy intake and expenditure (including PA), the methods used to assess these, and the outcome of energy balance in pregnancy (gestational weight gain, GWG). Finally, this chapter will discuss intervention studies targeting diet and PA and their outcomes.

1.1 Definition of obesity

Obesity is defined as 'excessive body fat accumulation that may impair health' according to the World Health Organization, WHO (WHO Media Centre, 2011). A simple index of weight-for-height known as body mass index (BMI) is commonly used to identify overweight and obesity in adults and is calculated as a person's weight in kilograms divided by the person's squared height in metres (kg/m^2). According to the WHO's definition, a BMI of ≥25.0 is considered as overweight and ≥30.0 is obese. Obesity can also be categorized further as class I (30.0 to 34.9), class II (35.0 to 34.9) and class III (≥40.0).

1.2 Prevalence of obesity

Obesity has progressively become a global epidemic that constitutes one of the biggest current health problems. Worldwide obesity has been rapidly increasing since the 1980s. Overweight and obesity have been deemed as serious health threats and are now the fifth leading risk factor for global deaths (WHO Media Centre, 2011). In the United Kingdom (UK), the rate of obesity among adults has more than doubled since 20 years ago, making the UK the most obese country in the European Union (Figure 1, Organisation for Economic Co-operation and Development (OECD), 2010).

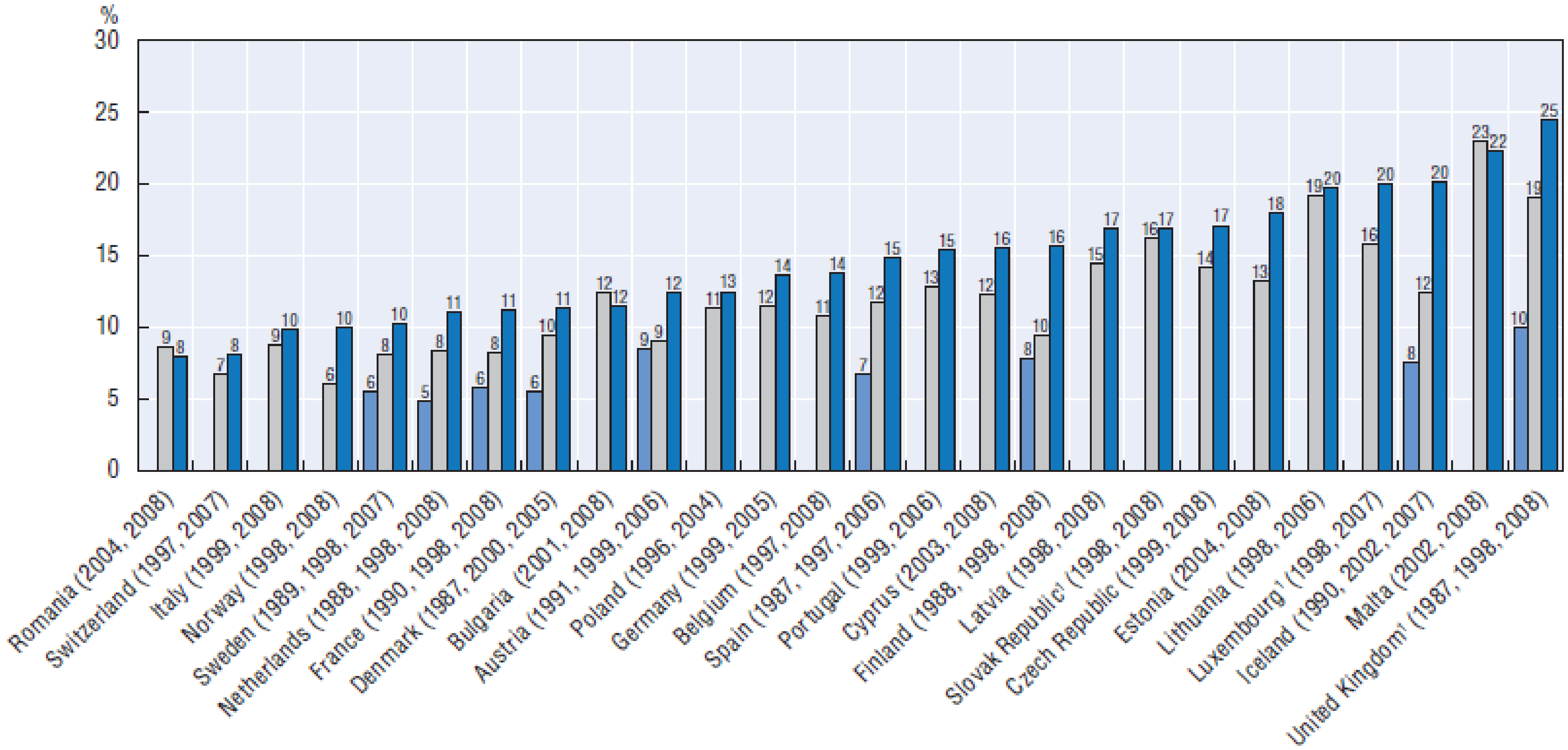


Figure 1.1

Increasing obesity rates among adults in European Union countries (sourced from Health at a Glance: Europe 2010, OECD Health Data, 2010)

The raised BMI trend is also seen in women with a quarter of the UK female population (aged 19 to 64 years) categorized as obese in 2008 (WHO Media Centre, 2011). The trend is similar in Scotland. The 2009 Scottish Health Survey found that 26.4 % of women aged 16 to 64 years were classified as obese (BMI ≥30.0) and 3.6% severely obese (BMI ≥40.0) (Gray and Leyland, 2009). This means that more women are now entering pregnancy with excess weight. Regional studies have estimated that the incidence of maternal obesity (defined as BMI ≥30.0 at antenatal booking) was approximately 16-19% in the UK (Heslehurst et al, 2007, Kanagalingam et al, 2005), which was almost parallel to the obesity incidence in the general population. This was confirmed by a recent national report by the Centre for Maternal and Child Health Enquiries (CMACE, 2010). After a 3-year UK-wide Obesity in Pregnancy project, the committee revealed that about 5.0% of UK maternity population had a BMI≥35.0 (class II and class III obesity) at any time point during their pregnancy. This translates into approximately 38,500 (or 1 in 20) maternities each year. The prevalence of expecting mothers with a BMI ≥40.0 is 2.0% and with a BMI ≥50.0 (super-morbid obesity) is 0.2%. With growing levels of obesity in the general population, this number is most likely to increase.

1.3 Complications of maternal obesity

Obesity in pregnancy has become an important obstetric risk factor, not only due to its increasing prevalence, but also because of the serious impact that it has on the health of the women and that of her offspring.

1.3.1 Maternal complications

It is well established that excess adiposity in pregnant women is associated with many adverse pregnancy outcomes. Obesity is associated with increased maternal mortality rates. According to the latest CMACE report, 27% of maternal deaths in the UK in 2006-2008 were amongst obese women (Lewis, 2011).

A number of reviews have shown that obesity before and during pregnancy constitutes a major risk factor for the development of hypertensive disease (hypertension and pre-eclampsia), diabetes (pregestational and gestational) and thromboembolism (Ruarger-Martin et al, 2010, Sirimi and Goulis, 2010, Tsoi et al, 2010, Jarvie and Ramsay, 2010). This 'metabolic syndrome of pregnancy' has been attributed to decreased insulin sensitivity, which occurs even in normal pregnancy (Catalano, 2010). Obesity also predisposes to respiratory disorders (asthma and sleep apnea), and infections (urinary tract infections, wound infections and endometritis) (Jarvie and Ramsay, 2010, Castro and Avina, 2002).

During birth, obese mothers also have a higher prevalence of postdates delivery with increased rates of labour induction (Jarvie and Ramsay, 2010). A systematic review and meta-analysis investigating the effect of obesity and the risk for caesarean section delivery found the need for surgical delivery to be more frequent in obese as compared to normal-weight mothers (Poobalan et al, 2009, Callaway et al, 2006). Doherty et al demonstrated in n=2,827 women that the rate of caesarean deliveries was 6.9% in normal-weight women, 9.8% in overweight women, and 12.7% in obese women (Doherty et al, 2006). Surgery in obese patients is of great concern due to greater anaesthetic risks during surgery and susceptibility to post-operative complications such as post-partum haemorrhage, deep venous thrombosis, wound infection and post-partum uterine infection (Sirimi and Goulis, 2010, Smith, Hulsey and Goodnight, 2008).

Postnatally, obesity in mothers is associated with an increased risk of lactation failure or delay in establishing lactation (Rowlands et al, 2010). Mechanisms are unknown but suggested reasons include abnormalities in prolactin response in obese women, or physical factors such as technical difficulties in feeding with large breasts (Rowlands et al, 2010).

1.3.2 Offspring complications

Obesity during pregnancy also increases risks of perinatal mortality. A recent systematic review and meta-analysis demonstrated that maternal overweight and obesity was the highest ranking modifiable risk factor, with population attributable risk factors of 8-18% annually across 5 high-income countries (Flenady et al, 2011). In the UK, it was reported that the stillbirth rate in women with BMI ≥35.0 (8.6 per 1,000 singleton birth) was twice as high as the national stillbirth rate, and that the risk increases with increasing obesity (CMACE, 2010).

Studies have illustrated that maternal obesity is not only associated with increased risk of perinatal deaths, but also with an increased risk of congenital abnormalities. Stothard et al (2009) found that obese women were nearly twice as likely to have a baby with neural tube defects. It was also found that the mothers of babies born with congenital anomalies such as spina bifida, heart defects, hydrocephaly, cleft lip and palate, and other structural anomalies, are more likely to be obese.

Excess adiposity in mothers has been associated with both small-for-gestational age, SGA (BWT <10^{th} percentile) and large-for-gestational age, LGA (BWT >90^{th} percentile) neonates (Ruarger-Martin et al, 2010, Rajasingam et al, 2009, Boney et al, 2005). Infants of obese mothers also have a higher rate of fetal macrosomia (birthweight >4kg) (Sirimi and Goulis, 2010, Tsoi et al, 2010). Other than being large at birth, studies have also demonstrated that these babies are also more susceptible to become obese children or adults, with the associated increased risks of metabolic or vascular diseases which may be attributed to obesogenic genes and/or environment shared between a mother and her child (Simmons, 2011, Rowlands et al, 2009, Heslehurst et al, 2008, Boney et al, 2005). This creates an undesirable circle that passes obesity from one generation to the next.

Indeed, research has shown events in early life may permanently determine long term health outcomes into adulthood, a concept known as the fetal origin of chronic diseases

(Barker, 1995). Barker postulated that exposure to poor nutritional conditions in-utero and in early postnatal life lead to alterations in development of vital organs, tissues and systems. These alterations may be protective in the short-term but may predispose to metabolic and cardiovascular diseases at older ages (Barker, 1995). Furthermore, it has been demonstrated that this increased chronic diseases risk in the offspring is highest when thin infant size at birth is combined with maternal obesity (Forsen et al, 1997). Although the Barker hypothesis has focused on undernutrition in utero, it is now becoming apparent that maternal obesity may itself be a 'programming' factor. Studies suggest that maternal adiposity may critically influence the fetal metabolic pathway programming and its risk of developing obesity, cardiovascular diseases, diabetes and cancer in later life (McMillen et al, 2008, Ozanne, Fernandez-Twinn and Hales, 2004). This has been described as the 'developmental overnutrition' hypothesis (discussed in more detail in section 1.7).

1.3.3 Economic implications to healthcare providers

The health implications for mothers and babies resulting from obese pregnancy also have important economic consequences. Increasing BMI in the obstetric population incurs higher financial costs to healthcare providers due to greater needs for prenatal and postpartum care and longer hospital stays (Rowlands et al, 2010, Callaway et al, 2006). In a retrospective cohort study involving 13,442 pregnancies, Chu et al (2008) reported that the mean length of hospital stays was significantly greater among women who were overweight (3.7 days), obese (4.0 days), very obese (4.1 days) and extremely obese (4.4 days) than among women with normal weight (3.6 days), and most of this increased in length of stay was associated to increased rates of caesarean delivery and other obesity-related high-risk conditions. In addition, there were significant associations between increased BMI and higher needs for prenatal fetal tests, obstetrical ultrasonographic examinations, medications, and prenatal visits to see physicians (Chu et al, 2008). Caring for obese patients also involves other everyday practical problems for healthcare providers such as difficulty in lifting patients, obtaining accurate blood pressure measurement, locating venous access, and providing adequate size examination couches, trolleys, beds and operating theatre tables (Catalano and Ehrenberg, 2006).

1.4 Gestational weight gain

Pregnancy has been proposed as a critical period that contributes to the development of obesity, for both the mother and her baby (Tovar et al, 2010). There are currently no formal, evidence-based guidelines for weight gain during pregnancy from the government or professional bodies in the UK. In the United States, the Institute of Medicine (IOM) has recently revised their 1990 GWG recommendation (Rasmussen and Yaktine, 2009) to account for the increased prevalence of overnutrition (instead of undernutrition previously) in pregnancy. The guidelines were developed to minimize negative health consequences of inadequate or excessive weight gain for both mother and baby. The guidelines were provided according to pre-pregnancy BMI classifications as presented in Table 1. The committee updated the recommendations for obese pregnant women. Instead of only giving a minimum total GWG of 6.8kg as stated in the previous guideline, it now provides a range and upper limit of weight between 5 to 9kg. This recommendation is for all obese (BMI>30.0) women. Insufficient scientific evidence at the time the guidelines were constructed prohibited provision of specific recommendations by obesity class or to support a public health suggestion to recommend a weight gain of below 5kg (Rasmussen et al, 2010).

Weight Category	BMI (kg/m^2)	Total recommended weight gain (kg)
Underweight	< 18.5	12.7 -18.2
Normal weight	18.5 – 24.9	11.4 - 15.9
Overweight	25.0 – 29.9	6.8 - 11.4
Obese	> 30.0	5 - 9

Table 1.1

IOM (2009) guidelines for weight gain during pregnancy

In general, weight gain in pregnancy is inversely associated with BMI at booking as shown by information gathered by CMACE (2010). GWG was calculated for 1,505 women in the Obesity in Pregnancy National Project and it was demonstrated that mean weight change between the first and third trimester was inversely correlated with first trimester BMI status, and total weight gain was reduced with increasing obesity classes from mean 14.5kg in BMI 30-35 to 7.3kg in BMI ≥50 (CMACE, 2010). However, the overweight and obese groups were more frequently found to have higher than IOM recommended weight gain during pregnancy as compared to underweight or normal weight groups (Rasmussen and Yaktine, 2009). A similar finding was also documented in a US population-based retrospective cohort study involving 570,672 women. Among overweight and obese study participants, 51% gained excessive weight according to the latest IOM recommendations, even though obese women were observed to gain the least average weight (mean 11.4 kg; range -12.2 to 34.9kg) as compared to underweight (15.9; 5.4 to 35.8kg), normal weight (15.7; 1.4 to 33.6kg) or overweight (14.4; -1.4 to 34.9kg), women (Park et al, 2011).

GWG within the IOM recommendations has been associated with better pregnancy, labour, delivery, neonatal, infant and child health outcomes, and healthier maternal and birth weight (Olson, 2008). On the other hand, increased GWG may increase risk for detrimental pregnancy outcomes. There is evidence for an association of weight gain above IOM recommendations with maternal complications such as the need for caesarean delivery (Viswanathan et al, 2008).

Excessive GWG may lead to weight retention after pregnancy. Literature reviews have demonstrated that that gaining more than recommended weight results in an increase in postnatal weight retention (Siega-Riz, Evenson and Dole, 2004, Gunderson, Abrams and Selvin, 2000). Evidence from a 21-year postpartum follow-up in a prospective cohort of 2,055 women indicated that maternal BMI increased on average by 0.52kg/m^2 for 0.1kg/week greater GWG, with a greater increase in BMI for women defined as having excessive GWG based on IOM recommendations (Mamun et al, 2010). The risks of retaining pregnancy weight are higher for women who have low income (Olson et al, 2003) and who are overweight or obese (Chang et al, 2008, Nohr et al, 2008). This retained weight, together with subsequent weight gain particularly during following pregnancies, has been proposed as a major contributing factor to the development of obesity or worsening of obesity severity among women (Artal, Lockwood and Brown, 2010).

GWG has been demonstrated to be significantly and positively associated with infant BWT in a prospective cohort study involving 2,670 mothers (Frederick et al, 2008). This was supported by reviews including a total of 35 studies which observed that excessive GWG was associated with increased BWT and LGA babies (Siega-Riz et al, 2009, Viswanathan et al, 2008). More recently, a large retrospective database study in the US showed that mothers who gained more than 24 kg during pregnancy added an average of 149 additional grams to their baby's BWT compared with those who gained about 8-10kg (Ludwig and Currie, 2010).This study analysed the data of 513,501 women and 1,164,750 of their children born across 15 years, and compared two or more infants born to the same mother. They also found that for every kilogram gained during pregnancy, the BWT increased by about 9.5g. In another study of similar design, proportions of LGA were demonstrated to be higher in obese women and increased with greater GWG, additionally the proportion of SGA infants decreased as pre-pregnancy BMI increased (Park et al, 2011). Excessive GWG has also been implicated in an intergenerational circle of obesity, where obese women deliver large daughters who have increased likelihood to gain too much weight before or during pregnancy, develop excess weight themselves and give birth to macrosomic babies (Catalano, 2003). Indeed, longitudinal studies have shown a relation between maternal weight gain during pregnancy and overweight and obesity in children and teenagers (Crozier et al, 2010, Oken et al, 2008, Oken et al, 2007). A population-based cohort study on 2,432 (male and female) individuals showed that greater maternal GWG is associated with greater offspring BMI at 21 years of age with offspring BMI was on average 0.3kg/m^2 higher for each 0.1kg/week increase in weight gain during pregnancy (Mamun et al, 2009). The effect of GWG also persists into offspring adulthood as shown in a prospective birth cohort study of 4,234 subjects (Schack-Nielsen et al, 2010). In this study, there was a significant increase in risk of obesity (odd ratio 1.08) at the age of 42 years for every kilogram of maternal GWG. Greater GWG during pregnancy as well as maternal BMI have also been associated with increased adiposity, waist circumference, and fat mass index in offspring aged 30 years in a Scottish cohort (Reynolds et al, 2010).

The IOM committee advised that gaining less weight than recommended, or losing weight during pregnancy, is not advised for obese women due to potential effects on child neurological development which are irreversible (Rasmussen et al, 2010). However, with excessive GWG and obesity recognized as independent risk factors for both maternal and fetal complications of pregnancy with significant long-term consequences, the single guideline provided by IOM for all obese women was queried by experts, particularly with the rising prevalence of obesity in women of reproductive age (Olson, 2008, Artal, Lockwood and Brown, 2010). Furthermore, studies have indicated that a single standard for optimal weight gain for all obese women may not be sufficient as the effect of weight gain on pregnancy outcomes differs in women with different classes of obesity. This was shown in a recent study of 5,550 obese women (BMI class I-III) (Bodnar et al, 2010). They found that as obesity became more severe, the prevalence of excessive GWG declined and weight loss increased. In this study, the risks for SGA, LGA and preterm births were minimized with GWG of 9.1 to 13.5kg for obesity class I, 2.2 to 9.0kg for obesity class II and 2.2 to <5.0kg for obesity class III. A similar finding was reported by another study on almost 74,000 pregnant women including 24% who were obese (Durie et al, 2011). Their study indicated that gaining less weight than recommended during pregnancy was associated with increased likelihood of having SGA babies in all BMI groups except obese class II and III (Durie et al, 2011). This finding was again supported by others which found that limited or no weight gain, or weight loss, in severely obese mothers was associated with favourable pregnancy outcomes such as lower risks of pre-eclampsia, caesarean delivery, SGA, LGA and pre-term births (Oken et al, 2009, Cedergren, 2007). In work commissioned by the IOM committee (Kiel et al, 2007) including a total of 4,814 obese (class I-III) women, GWG <5kg was not associated with deleterious effects in this group.

Not only does GWG determine both maternal and fetal health outcomes, but it also influences energy requirements. Four decades ago, Hytten and Leitch (1971) established that a total GWG of 12.5kg was associated with the best reproductive outcome in terms of infant BWT and survival, as well as maternal incidence of pre-eclampsia, based on data from >3,800 primigravidae who were eating without restriction. They developed a theoretical model which estimated that 0.9 kg (~7%) of protein and 3.8kg (~30%) of fat, are deposited in association with a 12.5kg GWG (Hytten and Leitch, 1971). Based on this, it was later estimated that the total energy cost of pregnancy was 85,000kcal or 300 kcal/day (Hytten and Chamberlain, 1980). This model was the basis of the Food and Agriculture Organization (FAO)/WHO/United Nations University (UNU)'s report on energy and protein requirements for pregnant women (FAO/WHO/UNU, 1985) and was also taken into consideration when the IOM was constructing their first GWG guidelines (IOM, 1990).

1.5 Total energy expenditure of pregnancy

A pregnant woman's energy requirement is determined by her total energy expenditure (TEE) and this is affected by basal metabolic rate, diet- and activity-related energy expenditure, as well as specific energy costs in pregnancy. The balance between energy expenditure and energy intake is important in determining healthy weight outcomes, including during pregnancy.

Human TEE is made up of three components; basal metabolic rate (BMR), thermogenic effect of food (TEF), and activity energy expenditure (AEE).

BMR represents the amount of energy expended while at rest, in a post-absorptive state. Accounting for approximately 70-80% of total daily energy expenditure in sedentary individuals, BMR can be predicted by the amount of lean body mass (Donahoo et al, 2004). BMR can be measured by respiratory gases (oxygen and carbon dioxide) using direct or indirect calorimetry. An approximate estimation can also be calculated through an equation using age, sex, height and weight (Harris and Benedict, 1918). BMR is normally increased in response to pregnancy due to increased fat-free mass (Forsum and Lof, 2007), particularly in the second half of pregnancy (Butte and King, 2005). This increase has been reported to be greater with increased pre-pregnant adiposity. One study which used the gold-standard doubly labelled water (DLW) technique to quantify this, showed increases of 7%, 16% and 38% in the first, second and third trimester, respectively, in women with higher BMI (≥ 26.0 kg/m^2) compared to 5%, 11% and 24% in normal weight women (Butte et al, 2004).

TEF is the energy expended above the BMR for food consumption i.e. to chew, digest, absorb and store foods. It normally accounts for approximately 10-15% of total daily energy expenditure (Prentice et al, 1996). TEF can be measured through repeated measurements of energy expenditure after meals using indirect calorimetry (Donahoo et al, 2004). Whether pregnancy influences TEF is unclear. One study in 10 pregnant women who all consumed the same test meal found that measured TEF varied from -63.5 to +26.3kcal/meal (Kopp-

Hoolihan et al, 1999). However, it is viewed as acceptable to consider TEF as relatively unchanged during pregnancy when expressed as a proportion of energy intake (Prentice et al, 1996).

AEE is energy expended for PA and is the most variable component of TEE (Forsum and Lof, 2007). Although an increase in energy cost of PA occurs due to weight gain, pregnant women may compensate for this by reducing the pace or intensity with which the activity is performed. They may also change their activity pattern e.g. by reducing time spent undergoing weight-bearing activities (Butte et al, 2004).

1.5.1 Measurement of total energy expenditure

The doubly-labelled water (DLW) is considered the gold standard technique in measuring the daily total energy expenditure (TEE) in humans (Schoeller and van Santen, 1982). Its principle is based on the use of water enriched with stable isotopes of hydrogen and oxygen in order to measure carbon dioxide production rates from which TEE can be calculated (as discussed in detail in Chapter 8 of this thesis). This technique has several advantages; it measures TEE objectively (without subjects having to keep a record or report a history), it minimizes interference with subjects' daily activities (thus it is not influenced by errors caused by subjects changing their behaviour due to monitoring) and it has been shown to be accurate (Schoeller, 2002). The method is also non-invasive and relatively simple to carry out as subjects are only required to give a few urine samples within a period of 7 to 14 days after ingesting the dose of labelled water (Schoeller, 2002). Its relative high cost, however, generally limits the use of DLW to smaller studies although there have been a few population studies which have used this technique in view of its advantages.

The development of DLW has also made it possible for TEE to be measured in normal daily living conditions, which represents an important index of human energy requirements (Forsum et al, 1992). This is particularly useful in pregnancy during which TEE is also influenced by additional pregnancy costs and changes in AEE, amounts of which are still difficult to confirm (Forsum and Lof, 2007). TEE measured by DLW showed an increase throughout pregnancy in proportion to the increase in body weight, by 1%, 6%, and 19% over baseline in first, second, and third trimesters, respectively (Butte et al, 2004). The increment of TEE also differed according to maternal pre-pregnancy BMI with a mean rate of 2.0 ± 15.1, 7.4 ± 10.2, and 2.9 ± 16.2 kcal/gestational week for each low-, normal, and high BMI group of women (n=17, 34, and 12, respectively) throughout pregnancy (Butte et al, 2004). There was, however, substantial inter-individual variation in response to pregnancy, as indicated by the relatively large standard deviations in values obtained.

The DLW technique has also been recognized as one of the alternative methods to assess the accuracy of energy intake and PA reporting via comparison of self-reports against the measured TEE (Poslusna et al, 2009). Studies comparing TEE measured by DLW with energy intake from weighed or estimated food records in non-pregnant individuals demonstrated that habitual energy intakes were commonly underestimated (Trabulsi and Schoeller, 2001) and this occurred more frequently, and to a larger degree, in subjects who were overweight or obese (Hise et al, 2002). Studies have also reported inaccuracy of self-reported PA as compared against objective assessments including DLW, and its prevalence increased with increasing body fatness (Irwin, Ainsworth and Conway, 2001, Buchowski et al, 1999), as well as, sedentary lifestyle (Duncan et al, 2001).

1.6 Physical Activity in pregnancy

PA is an important component of a healthy lifestyle which is linked to improvements in physiological, metabolic, and psychological parameters, and as such, is also recommended during pregnancy. Maintaining light-to-moderate intensity PA has been documented to confer various benefits for maternal and fetal health. In mothers, this includes increased fitness levels and overall well-being, improvement of cardiovascular function, reduction in musculoskeletal discomfort, reduction in muscle cramps and lower limb oedema, mood stability, and attenuation of gestational diabetes and gestational hypertension, and (in women with normal pregnancies) shorter labour and decreased incidence of operative delivery (Melzer et al, 2010). Regular PA has also been shown to decrease fat mass, improve stress tolerance, and advance neurobehavioral maturation of fetus (Melzer et al, 2010). Since pregnant women benefit from regular PA in the same way as non-pregnant populations, the American College of Obstetricians and Gynaecologists recommended that in the absence of either medical or obstetric complications, pregnant women should be encouraged to adopt similar PA guidelines as recommended to their non-pregnant peers, of a minimum 30 minutes of moderate intensity activities for most, if not all, days of the week (Artal and O'Toole, 2003). Here in the UK, the National Institute for Health and Clinical Excellence (NICE) has recently produced a guideline encouraging pregnant women to undertake at least 30 minutes of moderate-intensity activity per day (NICE, 2010). Recreational PA such as brisk walking and swimming and strength-conditioning exercise is relatively safe and beneficial. The committee also discouraged women from being sedentary as much as possible.

There appears to be a consensus that light-to- moderate-intensity PA during a low-risk pregnancy does not lead to adverse maternal or neonatal outcomes, no abnormal fetal growth, and no increase in early pregnancy loss or late pregnancy complications (Melzer et al, 2010, Schlussel et al, 2008, Morris and Johnson, 2005). In fact, light-to- moderate-intensity PA may even be considered a protective factor for some outcomes (Takito et al, 2009, Schlussel et al, 2008). Available information regarding the effect of maternal PA on BWT is inconsistent. An increase, decrease, and no difference in fetal BWT have been reported by different studies which included 2 meta-analyses when comparing women who exercised during pregnancy with sedentary controls (Morris and Johnson, 2005). Lower BWT outcomes were reported by studies which included participants who continued moderate-to-high intensity PA well into the third trimester with mean BWT difference ranging between 86 and 500g lower in infants of exercising mothers than in infants of non-exercising mothers, and this was mostly associated with reduction in fetal fat mass (Morris and Johnson, 2005). On the other hand, studies which found increased BWT in infants of mothers who exercised during gestation, had examined women who were not fit or were sedentary prior to being pregnant and had just started an exercise regime during pregnancy (Morris and Johnson, 2005). Although the results were conflicting, there is consistent evidence that low-to-moderate PA is not associated with intrauterine or postnatal growth restriction or neurodevelopmental problems in children whose mothers were exercising in pregnancy (Morris and Johnson, 2005). It has also been reported that PA at low-moderate intensity confers a protective effect against low BWT (Takito et al, 2009). Other studies have reported an association between excessive or vigorous intensity PA at a frequency of more than 5 days a week, and specific activities i.e. climbing stairs or standing for long periods, with low BWT (Takito et al, 2009, Schlussel et al, 2008). Interestingly, several studies found an equally harmful effect on fetal growth in the sedentary group, with less activity energy expenditure associated with increased risk for low BWT and preterm delivery (Takito et al, 2009).

A review of 10 studies evaluating the effects of exercise on GWG and perinatal outcomes focused specifically on overweight and obese pregnant women (Nascimento et al, 2011a). Similar to findings in previous reviews carried out amongst general pregnant women, they found there were no clear effects of exercise in controlling GWG or on perinatal outcomes in overweight and obese pregnancy. They did, however, indicate that light-to-moderate intensity activity is safe for overweight or obese pregnant women with low medical risks, just as it is in the general pregnant women population (Nascimento et al, 2011a).

Although an increase in the energy cost of PA occurs due to weight gain, pregnant women may compensate for this by reducing the pace or intensity with which the activity is performed. They may also change their PA pattern e.g. by reducing time spent undergoing weight-bearing activities (Butte et al, 2004). Indeed, there is a trend for self-reported PA to be consistently reduced from early to late pregnancy in both normal weight and obese women, which occurs through both reduction of intensity as well as duration of PA (Guelinckx et al, 2010, Borodulin et al, 2008).

1.6.1 Physical activity assessment methods

One of the most popular methods to assess PA is by using self-reported questionnaires. Most of the PA questionnaires currently available are targeted for the general population. They have been validated in men or non-pregnant women and focus on moderate- and vigorous-intensity activities. The majority also do not include housework or childcare, which comprise a substantial portion of activity during pregnancy (Schmidt, Freedson and Chasan-Taber 2003). A PA assessment instrument has therefore been developed specifically for pregnant women (Chasan-Taber et al, 2004). This self-administered pregnancy PA questionnaire was designed to measure the duration, frequency, and intensity of total activity during pregnancy. It has been validated in 54 pregnant women against 7-day accelerometry data (Chasan-Taber et al, 2004).

Self-report measures are prone to errors associated with recall, perception, and cognitive ability which is estimated to be between 35 to 50% and can vary according to different age groups or disease conditions (Ward et al, 2005). A tendency to report in a socially desirable manner may also contribute to the self-reporting inaccuracy (Ward et al, 2005). Therefore, there is a need for PA to be measured objectively. One of the ways to do this is by using accelerometry, an instrumental technique which measures human movements by using a body-fixed device with sensor (accelerometer). This device is normally worn on certain body parts e.g. ankle, abdomen or wrist for a certain period ranging from 2 to 21 days, comprising of working and non-working days (except when bathing, swimming or sleeping) (Webb, 1991). Among adults, at least 3-5 days of monitoring are required to estimate habitual physical activity (Trost, McIver and Pate, 2005). Accelerometers monitor both frequency and intensity of movements. Advancement in technology has also made it possible for the instrument to be produced in small, lightweight and portable sizes which can be worn without altering movements (Mathie et al, 2003). Due to its quantitative measurement, accelerometry has also been widely used to validate other measures of PA (Ward et al, 2005) in general as well as obese pregnant women populations (Kinnunen et al, 2011, Evenson and Wen, 2010, Haakstad, Gunderson and Bo, 2010, Lof and Forsum, 2006).

1.7 Dietary intake in pregnancy

Maternal nutritional status during pregnancy is of extreme biological importance during pregnancy as it affects both short and long-term health of the mother as well as the baby (Fall, 2009). Extra dietary energy is required during pregnancy partly to compensate for the energy deposition in maternal and fetal tissues and the increase in BMR (Butte et al, 2004) as discussed in Section 1.8. Maternal undernutrition has been shown to have negative consequences by predisposing the fetus to metabolic and cardiovascular diseases in later life, as evidenced by the studies of infants whose mothers were exposed to the Dutch Hunger Winter famine in 1944-45 (Roseboom et al, 2011, Schulz, 2010). The composition of the diet also plays a role. In a follow-up study of individuals in a Scottish cohort, whose mothers were advised to eat high animal protein, low carbohydrate diet during pregnancy, offspring exposed to the most unbalanced diet had increases in adult blood pressure (Shiell et al, 2001), plasma cortisol (Herrick et al, 2003) as well as stress responsiveness (Reynolds et al, 2007).

However, with the increasing prevalence of overweight and obesity among women of childbearing age globally, the more prominent nutritional problem faced by pregnant women in the western societies is overnutrition, pre-pregnancy overweight and obesity, and excessive weight gain during pregnancy. Maternal obesity is associated with enhanced insulin resistance and this metabolic dysregulation may lead to marked elevations of glucose, lipids, and amino acids (King, 2006). Increased placental transfer exposes the fetus to this excessive energy fuel and thus the fetus often grows larger-for-gestational age, has extra fat stores and increased risk for diseases postnatally (King, 2006). The exposure to an obesogenic intrauterine environment may also be the key mediator to transmission of maternal-offspring obesity and the associated chronic diseases through its long-lasting effect on dysregulation of appetite, neuroendocrine and/or energy metabolism, as postulated in the 'developmental overnutrition hypothesis' (Armitage, Poston and Taylor, 2008). Additionally, it has been speculated that exposure to increased maternal intake of palatable foods alters the development of appetite regulation system and food preferences, which interacts to promote excess energy consumption thus predisposing the offspring to weight gain (Muhlhausler and Ong, 2011).

Despite its importance, currently there are no national data available to describe the nutritional status of pregnant women in the UK. Data are available from national dietary surveys indicating the nutritional status of women of reproductive age, which is likely to be the nutritional state in which they enter pregnancy. The most recent National Diet and Nutrition Survey (NDNS) highlighted that a high proportion of female adults consume high levels of saturated fat and sugars, only a third of female adults are eating the recommended '5-a-day' of fruit and vegetables, and intake of iron is still well below the Recommended Nutrient Intake level (Bates, Lennox, and Swan, 2011).

Dietary reference intakes for pregnant women are recommended to be 1,940kcal/day during early pregnancy with an additional 200 kcal/day during the second and third trimesters (IOM, 2005). The latest American Dietary Guidelines suggested energy intakes of 1,800, 2,000, and 2,200 kcal/day for non-pregnant women aged 19-50 years who are sedentary, moderately active or active, respectively (US Department of Agriculture and US Department of Health and Human Services, 2010). Information regarding food intake during pregnancy available from several published studies among general pregnant populations showed energy intakes of between 1,863 to 2,329 kcal/day during early pregnancy, and between 1,839 to 2,314 in late pregnancy (Mouratidou et al, 2006a, Moore et al, 2004, Mathews et al, 1999, Rogers and Emmett, 1998, Godfrey et al, 1996). Three of the studies which measured energy intake during both early and late pregnancy demonstrated that it is either unchanged (Moore et al, 2004, Godfrey et al, 1996) or only increased slightly (Mathews et al, 1999). In general, these values seem to correspond with the calorie recommendations. However, sufficient intake of energy does not necessarily represent adequate intake of nutrients. Studies also reported low micronutrients intakes, particularly of essential micronutrients such as folate, vitamin D, and iron during pregnancy (Scientific Advisory Committee on Nutrition, 2010). These inadequate intakes appear to be the continuation of an unhealthy diet followed during the pre-gestational period (Pinto, Barros and dos Santos Silva, 2009).

Food quality is just as important as quantity, and healthy food choices have been shown to be affected by maternal pregravid and gestational weight status. Low diet quality has been significantly associated with increased maternal adiposity both before and during pregnancy (Tsigga et al, 2011). More worryingly, quality of diet was also shown to be inversely associated with weeks of gestation. This implies that the overnutrition state in pregnant obese women is not indicative of diet adequacy, and this worsens as pregnancy advances (Tsigga et al, 2010). Diet quality during pregnancy is also heavily influenced by socioeconomic factors. Typically poor diets are consumed by women from socio-economically deprived areas (Mouratidou et al, 2006a) and with low educational attainments (Robinson et al, 2004). There is, however, insufficient data regarding either the nutritional status or the factors that influence it among severely obese pregnant mothers.

Unlike GWG, the association between energy intake in pregnancy and BWT is still inconclusive. A prospective cohort study of 224 pregnant women followed during pregnancy through until delivery, revealed that neither energy nor any of the energy-generating nutrients (carbohydrate, fat and protein) assessed during the second trimester of pregnancy was significantly associated with birth size (Lagiou et al, 2004). Even though this study reported a positive association of GWG with BWT, and that GWG was positively associated with total energy, protein, and fats, and inversely with carbohydrate, there were no associations between nutrition and birth size parameters. It could be that the study was not powered to detect such association with their sample size (n=224). A larger study (n=1,082) did find a significant effect of nutrients on BWT, and this was with respect to the glycemic index (GI) of dietary carbohydrates (Scholl et al, 2004). Increased maternal glucose levels have been linked to greater fetal growth and heavier BWT. A low GI diet has been documented to ameliorate the post-prandial glucose rise (Brand-Miller et al, 2003), as well as, being associated with reduced prevalence of LGA (Moses et al, 2006).

1.7.1 Dietary assessment methods

Habitual dietary intake can be assessed by a number of methods including food frequency questionnaire (FFQ), food diaries, and diet recalls. The semi-quantitative FFQ is the most extensively utilized dietary assessment tool in epidemiological studies, due to ease of completion and analysis, and better response rate, particularly if the study involves a large number of participants (Cade et al, 2002). Although it has been reported to give a reliable estimate of nutrient intake (Willet, 1994), there is a tendency for FFQ to overestimate food consumption and nutrient intake due to the difficulty of comparing standard portion sizes with the actual amount consumed (Erkkola et al, 2001). However, no dietary method is able to measure dietary intake without measurement error, and therefore there is no ‘gold standard’ in nutritional assessment (Masson et al, 2003). It is therefore of particular importance that the potential sources of error are taken into consideration (Cade et al, 2004). Any FFQ to be used in a particular study should be tailored to the typical food consumption of the population under study (Robinson et al, 1996). This is to ensure that the FFQ is being used appropriately and that it will yield accurate results from the study population.

Only one FFQ, which was established by the Scottish Collaborative Group (SCG), has been extensively utilized in pregnant women in Scotland. This FFQ, which was originally developed for the Study of Eczema and Asthma to Observe the Effect of Nutrition (SEATON) study in 1997, is self-administered and contains 170 updated food items (Martindale et al, 2005). It was designed to assess daily intake of 40 nutrients (including total energy, carbohydrate, protein, fat, including fatty acids). The FFQ has been well validated against a 4-day weighed record (Masson et al, 2003), but has not been validated in a population of obese pregnant women.

1.7.2 Validation of food frequency questionnaire

It is important to assess the validity (the degree to which a tool measures what it is designed to measure) of the FFQ in a subsample of the studied population as incorrect information may lead to false associations between dietary factors and markers of diseases (Cade et al, 2002). In epidemiological studies, the odds ratio or relative risk of disease is commonly associated with relative nutrient intakes within a study population hence it is not always necessary to obtain absolute nutrient intakes. Therefore, it is sufficient for an FFQ to be able to rank individuals correctly along the distribution of intake so that individuals with low intakes can be distinguished from those with high intakes (Masson et al, 2003).This can be assessed by comparing the information collected by the FFQ against other dietary assessment methods such as multiple food recall or food diary. FFQ can also be compared against quantitative methods such as nutrient biomarkers, or TEE measured by DLW technique which, as discussed earlier, is considered the benchmark method in determining TEE due to its precision and lack of bias (Cade et al, 2004). The food diary is the most common reference method used in FFQ validation studies among pregnant women due to its practicality and better acceptance by subjects (Brantsater et al, 2008, Errkola et al, 2001, Robinson et al, 1996). With regard to design issues in validation studies, some authors have concluded that size of the validation study did not make an appreciable difference, on average, to the results of the study. A review indicated that on average, large studies may not necessarily provide higher association between the FFQ and reference methods compared to relatively smaller studies (Cade et al, 2004). The method of administrating the FFQ, however, may have an influence on the results. Correlation coefficients between FFQ and reference method were better in interviewer-administered as opposed to self-administered, which might reflect the opportunity of the interviewer to immediately check for improbable or unlikely responses (Cade et al, 2004). However, factors such as the added financial costs, time, and the need for well-trained interviewers, have to be considered.

1.7.3 Accuracy of self-reported energy intake

Dietary measurement error creates major challenges in investigating relations between diet and disease in nutritional epidemiological studies. A common error is underreporting, which is reporting of implausibly low energy intakes. Several studies which have assessed reporting accuracy at population levels have shown that it is associated with factors such as age, sex, and psychological characteristics, and with increased BMI (Poslusna et al, 2009, Scagliusi et al, 2009). Reduced reporting accuracy has also been reported in pregnant women, particularly in those with high pre-pregnancy BMI (Derbyshire et al, 2006), and there is a trend for this to increase with advancing gestation (Forsum and Lof, 2007). Underreporting is prevalent across dietary assessment methods, and over time when comparisons are made in the same individuals (Black and Cole, 2001). It is also commonly characterized by a tendency to report low intakes of foods which are deemed socially unacceptable such as those that are high in fat and simple sugars, and to report high intakes healthy foods such as vegetables and fruits (Livingstone and Black, 2003).

There are a few causes which may influence under-reporting such as misinterpretation of portion size consumed, failure to report foods eaten due to a respondent's memory lapses, the inconvenience of having to record everything that was eaten, or simply choosing not to report all foods eaten (Scagliusi et al, 2003). Other reasons for not reporting the true intake, particularly among obese individuals, are still debated. It has been suggested that their responses may be influenced by social-desirability bias, self-deception, or opportunistic but genuine intention to try and lose weight (Lissner, 2002, MacDiarmid and Blundell, 1998).

Underreporting of energy intake can ideally be assessed by using DLW which gives an objective estimate of energy requirements for weight maintenance (Poslusna et al, 2009, Tooze et al, 2004). However the relative high costs involved in using this technique limits its use. An alternative method to identify energy misreporters is by using a ratio of reported energy intake to BMR/energy requirement (calculated from formulas based on age, height, and weight) and by comparing this to a set of cut-off points (Poslusna et al, 2009). However, equations based on body weight for non-pregnant women are not accurate for use in pregnancy since metabolic rate increases disproportionately to the increases in total body weight (Forsum and Lof, 2007). The IOM (2005) proposed the use of estimated energy requirement formula specially formulated for pregnancy. This is derived from the sum of TEE of a woman in the non-pregnant state plus a median change in TEE of 8 kcal/week, plus the energy deposition during pregnancy of 180 kcal/day. Since TEE does not normally change much and GWG is minor during first trimester, no extra energy intake is required during the first trimester (IOM, 2005).

1.7.4 Factors that may influence dietary intake

Dietary intake is a complex behavior which is the results of environmental, social, historical, and psychological intertwining effects. Food choices can be influenced by a myriad of external factors such as affordability, knowledge, convenience, social support and relationships, as well as internal factors such as emotional status, personal preference, perceived control or self-efficacy in making food choices, and attitude and belief about health (Lawrence and Barker, 2009).

Metabolically, appetite and food intake are regulated by peripheral mechanisms which involve close interplay between adipose tissue, gastrointestinal tract, and the hypothalamus via actions of various hormones and peptides such as insulin, leptin, ghrelin and peptide YY (Neary, Goldstone and Bloom, 2004). On the other hand, mood and emotion also have physiological effects on appetite, and these in turn affect diet, and the effect is stronger in emotional eaters who often seek solace from food (Gibson, 2006). In pregnancy, psychological factors such as stress and depression have been associated with food intake by changing appetite (Marcus, 2009). Studies have also demonstrated a link between restrained eating behaviour and satiety among pregnant women. In a study comparing restrained eating behaviour among pregnant and non-pregnant women, those who were categorized as restrained eaters rated themselves to be less hungry and reported less difficulty controlling their food intake than their non-pregnant counterparts (Clark and Ogden, 1999). Another study which investigated the association of pregravid weight status, dietary restraint and psychosocial factors during pregnancy, found that extreme obesity (BMI≥35) was independently associated with increasing scores for perceived stress, trait anxiety, depressive symptoms, and dietary restraint, and decreasing scores for personal dispositions such self-esteem and mastery (Laraia et at, 2009).

Another predictor of food choices is socioeconomic and educational status. There is evidence that low income and education levels are consistently associated with higher rated of obesity as well as other chronic conditions such as diabetes mellitus, hypertension, and coronary heart diseases (Banks et al, 2006). Women with lower educational attainment have poorer quality diets than those of higher educational attainment, before or during pregnancy (Lawrence and Barker, 2009, Robinson et al, 2004). This could reflect the level of nutrition knowledge as it has been previously shown that more highly educated people demonstrate significantly better knowledge about nutrition (Parmenter, Waller, and Wardle, 2000). The relation between socioeconomic and educational status with diet quality may be explained by food cost (Aggarwal et al, 2011). Generally, better quality diets (which are characterized by higher consumption of whole grains, fresh fruits and vegetables, and lean meats, and low intakes of refined grains, saturated fats, as well as simple sugars) are more expensive i.e. cost more per calorie compared to than diets which are energy-dense but nutritionally poor (Darmon et al, 2005). This may result in reduced food affordability among low income groups and influence them to consume diets of poorer quality than people with higher socioecomic status, hence the socio-economic disparities in health (Banks et al, 2006).

1.8 Determinants of energy balance in pregnancy

In pregnancy, there is an additional component of TEE to account for energy expended for the synthesis of new fetoplacental tissue and the retention of fat and protein in the mother (Forsum and Lof, 2007). Major anatomical, physiological, and metabolic changes occur to support a pregnancy and extra energy is required to synthesize new tissue such as fetal mass, placenta, uterus and breasts from fat and protein stores. This consists of two components; the energy needed to synthesize appropriate amount of fat and protein stores, and the energy content of this fat and protein itself (Forsum and Lof, 2007). Due to this extra energetic component, it is commonly accepted that TEE during pregnancy in healthy well-nourished women is expected to increase. However, the magnitude of increment is still debatable due to the uncertainties regarding the optimal amount of fat and protein deposition, the amount of fat and protein extracted from body stores, as well as the possible modification of AEE either through metabolic economy such as enhanced sparing of energy, as well as the decrease in intensity, or the reduction in quantity, of movements (Byrne et al, 2011).

It is expected that the greater energy requirement during pregnancy is met by increased energy intake, but this is not always true. Studies have reported that food intake among expecting mothers shows little or no increase compared to pre-pregnancy intake (Kopp-Hoolihan et al, 1999, Durnin 1991, Durnin et al, 1987). However, this discrepancy was recently argued by Lof and Forsum (2007) to be due to under-reporting, which was suggested to be common among women (as discussed previously in Section 1.7.3).

Energy metabolism is influenced by several complex interactions, and each woman may cope in different ways to meet the extra energy requirements of pregnancy. It has been suggested in a review of studies that there are several possible ways through which energy balance can be manipulated to ensure the obligatory needs of pregnancy are met such as limited increment of BMR, mobilization of maternal fat reserves, decrease in PA, or an increase in food intake, and the options used depend on adiposity status, availability of foods, and PA patterns (King et al, 1994). It has been suggested that obese women, with their surplus of stored energy, may not even need to increase energy intake by much or resort to energy-sparing in order to meet the increased requirement of pregnancy.

Gain (or loss) in weight is determined by the balance between energy intake and expenditure. Indeed, studies have shown that energy intake and PA during pregnancy are associated with GWG (Streuling et al, 2011, Streuling et al, 2010). Excessive weight gain, which may contribute to the development of obesity in the general population, is associated with a consistent excess of energy intake coupled with inadequate physical activity (WHO Media Centre, 2011). This should also explain the cause of obesity and excessive GWG in pregnant women. This was demonstrated by a prospective cohort study which found that total energy intake was higher, whereas total PA was lower, among pregnant women with excessive GWG (Stuebe et al, 2009).

It is plausible that diet may play a role in influencing pregnancy outcomes of women with excess weight. A recent systematic review investigating associations between diet and GWG in singleton pregnancies found that 5 studies reported positive associations between energy intake and GWG, whereas 3 reported no significant association (Streuling et al, 2011). Further significant positive associations with GWG were observed for increased animal lipids, energy density, and number of different food servings per day, whereas inverse associations were observed between GWG and high carbohydrate and vegetarian diets. Based on this, it was concluded that restrictions in energy intake during pregnancy may be a potential intervention strategy to prevent excessive GWG. However, not all of the studies reviewed made appropriate adjustment for confounding factors such as maternal age and BMI, and thus this might have influenced the strength of the relationships between GWG and nutrition (Streuling et al, 2011). No studies have specifically examined the relationship between dietary components and GWG in severely obese pregnant women.

Other than diet, PA is another modifiable behavioural risk factor which may have an important role in influencing energy balance and its outcome, gestational weight gain (GWG). A recent randomised controlled-trial involving general pregnant women (n=110) found that after 12-week of tailored exercise intervention, the exercise group showed a significantly higher increase in self-reported sports/exercise activities (0.9 MET-hours/week vs. -0.01 MET-hours/week) as compared to the control group who received information regarding general health and wellness during pregnancy (Chasan-Taber et al, 2011). However, published reviews have found no clear effect of PA on weight gain during pregnancy due to inconsistent results among studies (Schlussel et al, 2008, Morris and Johnson, 2005). These reviews have included several observational studies which found either no significant difference or significantly less GWG (between 1.8 to 3kg) in women who exercised during pregnancy and those who did not (Morris and Johnson, 2005). This discrepancy was attributed to a lack of standardization as to the definition, type, frequency, intensity, and duration of PA evaluated in most of the studies reviewed (Schlussel et al, 2008). However, a recent systematic review suggested that PA intervention in pregnancy might be successful in restricting GWG (Streuling et al, 2010). From their meta-analysis of 12 studies, it was demonstrated that even though the results of the individual studies were not consistent (most probably due to varying degree of methodological quality), there was a small, but significant reduction of mean GWG in the intervention (exercise) groups. The benefit of exercise was also showed by another review of evidence-based studies (Gavard and Artal, 2008). It was suggested that through reduction of GWG, exercise in pregnancy could prevent or limit adverse maternal and fetal morbidities such as gestational diabetes, pre-eclampsia, BWT, and delivery outcomes (Gavard and Artal, 2008).

1.9 Interventions during pregnancy: modifications of diet or physical activity

Pregnancy is a period in life when women receive closer medical attention than at other times in their adult lives, and are often more likely to be motivated to make lifestyle changes, for the health benefits of themselves and particularly of the baby (Phelan, 2010). Therefore pregnancy presents an ideal time for promotion of healthy behaviour, which includes judicious diet and PA that can be maintained in the long term. However, any intervention to be taken during pregnancy should be based on clinical evidence which sufficiently demonstrates a desirable balance between benefit and risk to ascertain the wellbeing of both the mother and her baby.

Among the modifiable behavioural risk factors, nutrition and PA are viewed as essential and are increasingly targeted in antenatal intervention programs, mostly for prevention of excessive GWG as evidenced in Table 1.2. Clinical studies determining the effectiveness of such interventions in general pregnant women populations have reported inconsistent findings. A recent meta-analysis on 13 controlled trials and qualitative studies of diet and PA interventions indicated that there was no significant effect on weight gain during pregnancy (Campbell et al, 2011). Streuling et al (2010) pooled the effects of 9 randomized and non-randomized trials and concluded that there was a small, but statistically beneficial effect of interventions based on PA and dietary counselling, particularly when combined with weight monitoring. Another review found that GWG was reduced only in subgroups such as normal weight, obese, or low income, or not at all (Skouteris et al, 2010). They also demonstrated that while studies reported significantly less weight gain in intervention groups, less then half of them showed that these women actually managed to adhere to recommended guidelines.

The benefit of providing dietary and/or PA interventions for overweight and obese women also remains uncertain. Overall, studies have shown no statistically significant differences on GWG between women who received antenatal interventions and those who did not (Dodd et al, 2010, Guelinckx et al, 2008). However, these reviews are based on a limited number of studies (n=7 each in Dodd et al and Guelinckx et al) and further research is required. The reason for the lack of effectiveness of intervention programs is debatable. Successful intervention in overweight and obese pregnant women may require carefully designed lifestyle programs which are personally tailored for each individual with regular follow up sessions, as shown by some studies (Mottola et al, 2010, Artal et al, 2007). It has also been suggested that interventions to date have been associated with limited success due to lack of consideration of psychological factors (Rasmussen and Yaktine, 2009, Walker, 2007). Eating behaviour such as food choice, for example, is governed by an interdependent interaction between psychological, physiological, sensory, and emotional influences (Gibson, 2006), and this may become even more complicated when added with the complexity of obesity itself. Any intervention strategies should therefore address psychosocial as well as other emotional, cognitive and situational barriers which may impede behaviour change before changes in eating and activity behaviour can be intervened (Gardner et al, 2011, Skouteris et al, 2010).

Table 1.2

Summary of intervention studies which aimed toprevent excessive weight gain in pregnancy

Authors	Study population	Interventions	Control group	Sample size	GWG outcome
Hui et al (2011)	Non-diabetic pregnant women (<26 weeks of gestation)	Community-based group dietary counseling, exercise sessions and individual home exercise.	Received PA activity and food intake surveys at enrolment and 2 months after that	Intervention gp: n=88 Control gp: n=102	No. of women who exceeded recommended GWG: Intervention gp: 54% Control gp:35% *(P=0.008)*
Phelan et a (2011)	Non-diabetic pregnant women (between 10-16 weeks gestation). Normal-weight (NW, BMI 20-26) & Overweight/obese (OW/OB, BMI>26)	1 counseling + weekly mailed materials on healthy eating (calorie goals set at 20 kcal/kg/day). Encouragement for 30mins of walking most days of the week (pedometers were provided). Discussion on appropriate GWG (personalized GWG graphs with feedback given after each visit). Women who were under/over GWG guidelines received supportive phone calls with structured meal plans + specific goals until GWG return to appropriate levels.	Received standard prenatal care, nutrition counseling & newsletters on pregnancy-related issues.	Total intervention gp: n=201 Total control gp: n=200	No. of women who exceeded recommended GWG: NW gp: Intervention: 40% Control: 52% (*P=0.003*) OW/OB gp: Intervention: 61% Control: 67% (*P=0.033*)
Mottola et al (2010)	Overweight and obese pregnant women with BMI ≥25 (including 15% with BMI ≥40)	Individualized nutrition plan with total energy intake 2,000kcal/day (40-55% of total energy from CHO). Walking program (30% of heart rate reserve) 3-4 times/week, pedometers provided to counts steps).	Historical cohort matched for pre-pregnancy BMI, maternal age and parity.	Intervention gp: n=65 Control gp: n=260	80% of women in intervention group did not exceed recommended GWG.

Authors	Study population	Interventions	Control group	Sample size	GWG outcome
Guelinckx et al (2010)	Obese, white pregnant women with BMI ≥29.	Passive gp: Nutrition, PA, and tips to prevent excessive GWG from a brochure. Active gp: Brochure and lifestyle education by a nutritionist in 3 gp-sessions throughout pregnancy.	Received routine prenatal care.	Passive gp: n=37 Active gp: n=42 Control gp: n=43	No. of women who exceeded recommended GWG: Passive gp: 48% Active gp: 46% Control gp:41% *(P=0.847)*
Asbee et al (2009)	General pregnant women (6-16 weeks gestation)	Standardized counseling session, patient-focused calorie value (40% CHO, 30% fat and 30% protein). Instructions to engage in moderate-intensity exercise minimum 3 times/week but preferably 5 times/week. Advice on (IOM 1990) GWG recommendation during 1st trimester.	Received routine prenatal care.	Intervention gp: n=57 Control gp: n=43	Adherence to IOM guidelines: Intervention gp: 61% Control gp:49% *(P=0.210)*
Kinnunen et al (2007)	Nulliparous pregnant women	5 counseling sessions on healthy eating (with weekly records of compliance to objectives), and how to increase leisure-time PA (with individual weekly physical activity plan).	Received routine prenatal care.	Intervention gp: n=49 Control gp: n=56	No. of women who exceeded recommended GWG: Intervention gp: 46% Control gp:30% *(P=0.053)*

BMI – Body mass index; CHO – Carbohydrate; GWG – Gestational weight gain; gp – Group; PA – Physical activity

1.10 Purpose of study

In summary, there is an increasing prevalence of maternal obesity, with documented detrimental effects of obesity in pregnancy to both mother and fetal health. Since maternal obesity may predispose to excess GWG, the lack of efficacy of intervention studies to ameliorate GWG through alterations in diet or PA is of concern. Obesity is linked to a consistent positive energy balance due to excess energy intake and insufficient PA. In pregnancy associated with severe obesity, little is known about the dietary and PA behaviours of this population of women. This knowledge is essential in order to be able to plan effective interventions. The suitability and appropriateness of using self-reported method in obtaining such information among severely obese pregnant women has also never been investigated. Therefore, the purpose of this thesis was to investigate dietary and PA behaviours in severely obese pregnant women, and in doing so, to evaluate the validity of the self-reported instruments used, as well as the prevalence of underreporting of self-reported energy intake in this study population. The possible role of diet and PA in determining pregnancy and birth outcomes was investigated by assessing associations between these and GWG/BWT. This research was carried out in a cohort of severely obese (BMI ≥40) and lean pregnant controls (BMI 20-25), who were recruited from an ongoing study of severe obesity in pregnancy at the Antenatal Metabolic Clinic, Royal Infirmary of Edinburgh, UK.

1.11 Hypotheses and aims

The hypotheses of this research were as follows:

1. Severely obese women consume more total calories and other nutrients than lean women throughout pregnancy.
2. Severely obese women do less total PA than lean women throughout pregnancy.
3. The predicted higher caloric intake and lesser PA during pregnancy in severely obese compared to lean women is associated with higher GWG and increased offspring BWT.

The primary aims of this research were to:

1. assess dietary intake using a validated self-administered questionnaire (discussed in Chapter 4)
2. assess PA using a validated self-administered questionnaire (discussed in Chapter 6)
3. assess whether self-reported diet and PA were associated with GWG and offspring BWT (discussed in Chapter 7)

The secondary aims of this research were to:

1. assess the validity of self-reports against food diary (discussed in Chapter 3), and quantitatively using accelerometry (discussed in Chapter 6), in subgroups of participants
2. assess the prevalence of under and over-reporting of energy intake (discussed in Chapter 5)
3. carry out a pilot study to assess the feasibility of using DLW technique to assess TEE, as well as self-reporting accuracy, in a subgroup of participants (discussed in Chapter 8).

CHAPTER 2

Methods and Materials

Chapter 2

2.1 The Antenatal Metabolic Clinic

The University of Edinburgh and NHS Lothian Hospitals Trust established an Antenatal Metabolic Clinic (AMC) in Edinburgh in August 2008, with support from Tommy's the Baby Charity (www.tommys.org), to look after pregnant women who are severely obese at antenatal booking (body mass index, BMI ≥40). The clinic's main focus is to tackle and further understand problems that arise in pregnancy due to maternal obesity. Women attending this clinic receive their normal antenatal care and are characterised in detail in terms of body composition, metabolic profile, stress and anxiety levels and blood pressure throughout pregnancy. They are also referred to see a specialized dietitian who provides them with tailored advice about healthy eating in pregnancy. A parallel normal-weight control (BMI 20-25kg/m^2) control group of pregnant women has been recruited since March 2010. These women receive their antenatal care in the community but attend the research clinic for research visits. This ongoing study is called the Hormones and Inflammation in Pregnancy (HIP) Study.

2.2 Study design

This project involves collection of case-control, validation, and cohort studies carried out as nested studies within the HIP study and designed to assess energy intake and expenditure in severely obese pregnant women. Assessment and comparison between obese and lean groups of food intake, appetite, general nutrition knowledge, and eting behaviours (Chapter 3), misreporting of energy intake (Chapter 5), and physical activity, PA (Chapter 6), were of case-control design. Comparison between the Scottish Collaborative Group Food Frequency Questionnaire (SCG-FFQ) and food diary (FD) (Chapter 4), Pregnancy Physical Activity Questionnaire (PPAQ) and accelerometry (Chapter 6), SCG-FFQ/PPAQ and doubly-labelled water (DLW) (Chapter 8), were validation studies. Associations between diet/PA and gestational weight gain (GWG)/birth weight (BWT) (Chapter 7) in obese and lean groups were tested using a cohort study design. In addition, the DLW assessment of TEE also served as a pilot study to explore the feasibility of using this technique in a larger study.

2.3 Ethical approval

The ethical approval for the HIP study was obtained from Lothian NHS Research Ethics Committee (REC reference number 08/S1101/39) and included the permission to use the SCG-FFQ and FD. The ethical approval for the EBIP study was obtained from the same research ethics committee (REC reference number 09/S1103/03). This covered the energy expenditure and dietary behaviours studies using the PPAQ, accelerometry, General Nutrition Knowledge Questionnaire (GNKQ), Council on Nutrition Questionnaire (CNAQ), Dutch Eating Behaviour Questionnaire (DEBQ), and DLW methods.

2.4 Recruitment of study participants

2.4.1 Eligibility for the HIP Study

Severely obese pregnant women (study group) and lean pregnant women with (control group) and aged between 16-50 years, and with a healthy singleton pregnancy were eligible for the study.

2.4.2 Recruitment of HIP Study participants

Severely obese pregnant women were referred to the AMC by their community midwives when they were seen at their first antenatal booking visit. For recruitment of the controls, a research nurse visited community clinics and invited lean pregnant women to participate in the study. Women who were interested in taking part were telephoned by the research midwife and an appointment made for the women to attend the AMC. A leaflet with details about the HIP study and the AMC was distributed to both of these groups. The recruitment for the HIP study commenced in June 2008.

2.4.3 Baseline data collection for HIP Study

If they agreed to take part, obese pregnant women were invited to attend the AMC on 3 occasions; between 12-20 weeks, at 28 weeks, and 36 weeks gestation, in addition to their routine antenatal care. They were asked to give their personal details and to sign a consent form. The lean pregnant women were invited to attend the AMC on 3 occasions; between 12-20 weeks, at 28 weeks, and 36 weeks.

Anthropometric measurements were taken by the clinic staff. Height was measured with a SECA 216 stadiometer (SECA Ltd, Birmingham, UK). The subject was asked to stand with their shoes off and with their back against the stadiometer and with the head positioned up and facing straight ahead. The head piece was brought down onto the upper most point on the head (compressing the hair) and measurement of height was taken to the nearest 0.5cm. Weight was measured with a SECA 959 chair scale (SECA Ltd, Birmingham, UK). The subject was asked to remove any extra layers of clothing, bags, or any items in her pockets. The scale was tared to zero and weight measurement was taken to the nearest 0.1kg.

Body composition (body fat mass, fat-free mass, and total body water) was measured by using Tanita TBF-300M body composition analyzer (Tanita UK Limited, Middlesex, UK). This equipment estimates body fat based on the principle of bioelectrical impedance analysis (Jebb et al, 2000). As muscle tissue (fat-free mass) is an electric conductor whereas adipose tissue is a resistor, these can be measured via regression equations when a very low voltage electric current (50kHz) is applied through the body to estimate body impedance (resistance) to electric current (Kyle et al, 2004). Subject's information such as age, gender, and height, were manually entered into the equipment before subject was asked to stand on the weighing platform with bare feet. The measurement results were produced in a print-out.

The women were asked to fill in questionnaires about their social and medical history during the first visit (between 12-20 gestational weeks). They also completed stress and anxiety levels questionnaires twice during pregnancy; during first visit (early pregnancy) and late pregnancy (between 28-32 gestational weeks). In addition, they were asked if they would like to take part in other more detailed studies during the pregnancy.

2.4.4 Recruitment of EBIP Study Participants

The recruitment for the EBIP study commenced in August 2008 and ended in August 2011. The women who were enrolled in the HIP Study and had indicated that they would be interested in volunteering for other more detailed studies within the AMC were invited to take part in the EBIP study. A total of 175 (80%) obese and 87 lean women (99%) were included in the EBIP study. 18 women (17 obese and 1 lean) declined. In addition, because the EBIP study commenced two months later than the HIP study, 26 women (all obese) were missed from being approached. Overall, the demographic characteristics such as age, BMI at booking, parity, and ethnicity, were found to be not significantly different between the HIP study participants who were and were not included in EBIP study (refer Appendix B). However, a higher percentage of the participants who did not take part in EBIP study were of low and high Deprivation Category (DEPCAT) status based on postcodes (Mcloone, 2003), compared to those who did (*P=0.004*).

2.4.5 Baseline data collection for EBIP Study

The SCG-FFQ, PPAQ, GNKQ, CNAQ, and DEBQ, were given out routinely by a research midwife to all women. This was done twice during pregnancy (except for the GNKQ and DEBQ which were given only once); early (during the first visit to the clinic, between 12-20 gestational weeks) and late pregnancy (during second or third visit to the clinic, between 28-32 gestational weeks). The women were also approached personally to ask if they would like to take part in other components of EBIP study e.g. keeping a FD for 4 days, wearing an accelerometer for 3 days, and/or doing the DLW study for 14 days. The study protocol for the EBIP study is illustrated in Appendix A.

2.5 Collection of dietary intake data

2.5.1 Scottish Collaborative Group Food Frequency Questionnaire

The semi-quantitative SCG-FFQ version 6.6 (Scottish Collaborative Group, University of Aberdeen, UK) was used to measure food intake (refer Appendix M). This has been validated against 4-day weighted diet records in healthy adults (Masson et al, 2003). The SCG-FFQ consists of a list of 170 foods and drinks which are divided into 21 food groups. In this questionnaire, subjects are asked to describe the amounts and frequency of each food on the list that they have eaten over the last 2 to 3 months. This includes all their main meals, snacks, and drinks eaten at home or away from home e.g. at work, at restaurants or cafes and with friends or family. For each food, an example of one measure is provided to help them estimate how much of the food they usually have e.g. '1 medium slice' for bread. The amount is stated in Measures per Day (1 to 5+ measures) and the frequency the food is consumed in Number of Days per Week (1 to 7 days a week, 'R' for foods which are rarely or never eaten, and 'M' for foods which are consumed between once a month to less than once a week). If they chose 'R' for frequency, subjects were asked to leave the amount section blank. In addition, the SCG-FFQ included a field 'Other foods and drinks', in which the subjects could add any other foods or drinks that they usually eat but were not listed in the FFQ. Subjects were also asked to report the type, amount and frequency of vitamins, minerals and food supplements if taken, recent dietary changes and special diets or dietary restrictions, if there were any. An instruction sheet where important points were highlighted was enclosed with each questionnaire (refer Appendix N).

2.5.2 Food diary

The SCG-FFQ has not been validated in severely obese pregnant women, therefore a subgroup of subjects (who attended the AMC between October 2008 to October 2009) was asked to complete a FD for this purpose. The chosen FD (Food and Drink Diary for Adults, 2006) is produced by the University of Aberdeen. Subjects from both obese and lean groups who had filled in the SCG-FFQ were invited to keep a FD for 4 days (3 week days and 1 weekend day). For each day, they noted down the date, day of the week, time of meal, the type and amount of food and/or drink eaten during each meal, and amount left over, if any. They were asked to record everything they ate and drank at home or outside the home, in as much detail as possible e.g. by describing the brand names, the type of bread/dairy products/cereals/drinks, type of fat or oil used in cooking, methods of cooking, ingredients used (for home-cooked meals). To help them describe the amounts of foods, 22 pictures of food portions are provided at the end of the FD. If they had more or less of the amount in the picture, they could describe the amount by writing ½ or 2 times etc. If appropriate, printed weights on packets foods were used. Subjects were also instructed to record any food leftovers at the end of the meal to avoid overestimation of food intake. They were also advised to do the recording at the time of eating, and not from memory at the end of the day. An example of one day's record is provided at the beginning of the FD.

2.5.3 General Nutrition Knowledge Questionnaire

A subgroup of subjects (who attended the AMC between January to December 2009) was asked to complete the GNKQ (Parmenter and Wardle, 1999). This is a validated semi-quantitative questionnaire which consists of four independent sections. Each section assesses a different aspect of nutrition knowledge; dietary recommendations, nutrient contents of foods, food choices, and diet-disease relationship. For each question, subjects were asked to choose the best answer (refer Appendix O).

2.5.4 Council on Nutrition Appetite Questionnaire

A subgroup of subjects (who attended the AMC between January 2010 to May 2011) was asked to complete the CNAQ (Wilson et al, 2005). This appetite assessment tool is a validated quantitative questionnaire which contains 7 questions about general perception about current appetite, hunger, food taste, number of meals eaten per day, and feeling of nausea when eating. Subjects were asked to choose one best answer for each question (refer Appendix P).

2.5.5 Dutch Eating Behaviour Questionnaire

A subgroup of subjects (who attended the AMC between September 2010 to August 2011) was asked to complete the DEBQ (van Strien et al, 1986) as shown in Appendix Q. The DEBQ consists of 33 items comprising 3 scales for the measurement of emotional eating (eating in response to emotion, 13 items), externally-induced eating (eating in response to food-related stimuli e.g. food sight and smell, 10 items), and restrained eating (attempts to refrain from eating, 10 items). Each item is measured on a 5-point Likert scale ('Never', 'Seldom', 'Sometimes', 'Often', and 'Very Often').

2.6 Collection of energy expenditure data

2.6.1 Pregnancy Physical Activity Questionnaire

The PPAQ (refer Appendix R) used in this study was a PA assessment instrument which was developed specifically for pregnant women (Chasan-Taber et al, 2004). The PPAQ was designed to measure the duration, frequency, and intensity of total activity during pregnancy. This self-administered questionnaire contains 36 questions about the time spent in 32 activities including household/caregiving, occupational, transportation, sports/exercise, and inactivity. It has been validated in 54 pregnant women against 7-day accelerometry data (Chasan-Taber et al, 2004).

2.6.2 Accelerometry

Accelerometry is a method of objectively measuring human movements by using a body-fixed device with sensor (accelerometer). The accelerometer used in this study was *Actical* (Mini Mitter Company, Inc., USA) which monitors the occurrence and intensity of motion. The amplitude and frequency of motion is then integrated to produce electrical currents of varying magnitudes; the higher the motion intensity, the higher the voltage produced. The *Actical* device stores this information in the form of activity counts (per minute). This activity monitor is lightweight, and can be worn on the hip, wrist or ankle. Although the hip position is considered to be the most accurate according to the manufacturer's manual, it was not possible in the study participants who were severely obese and pregnant. For comfort reason, they were asked to wear this device on their non-dominant wrist. Subjects were asked to wear the accelerometer for a 3-day period (2 weekdays and 1 weekend day). They were instructed to wear it for a complete 24 hours for each day, during all waking and sleeping hours. The accelerometers were removed during bathing or doing water sports activities. Subjects were asked to note down the time, duration and reason for taking off the device on any of the days, using a form provided. Prior to collecting data, the accelerometers were uploaded with set-up information such as subject's identity, gender, age, height, weight, and the start date and time. This was done by using the 'Write' function on the *Actical* software, and then loaded into the device by using *Actireader* (both were supplied by the manufacturer). The accelerometers were set to start recording data starting at 12am on the first day but subjects were advised to start wearing it before going to bed that night. If they forgot to wear it on the said time, they were advised to put it on as soon as they remembered and then to continue wearing it for the next 72 hours. The accelerometers were personally delivered to and collected from the subjects. The subjects were also given verbal, as well as written instructions (refer Appendix S) on how to wear the device.

2.6.3 Doubly-labelled water

The DLW technique uses stable isotopes (2-hydrogen, ^2H or deuterium, and 18-oxygen, ^{18}O) to accurately determine total daily energy expenditure. The regular hydrogen and oxygen in the water are replaced by these stable isotopes in enriched amounts so that they can act as tracers.

After a dose of the labelled water is consumed, these tracers will quickly equilibrate in body water . In normal-weight individuals the equilibrium process may only take 4-6 hours, but this may take longer in subjects with higher body weight (Schoeller, 1988). Deuterium (^2H) is eliminated from the body only as body water so its elimination rate is proportional to water turnover. ^{18}O is eliminated as body water and CO_2 so its elimination rate is proportional to water turnover and CO_2 production rate (kCO_2) (Lifson, Gordon, and McClintock, 1955). Therefore, the difference in the elimination rates of the two isotopes provides an estimate of kCO_2 and can be calculated as:

$$kCO_2 = (TBW/2.078)\ (1.01k_o - 1.04\ k_d) - 0.0246\ r_{GF}$$

where TBW is the total body water (mol), k_o is the oxygen elimination rate (per day), k_d is the deuterium elimination rate (per day), and r_{GF} is the rate of fractionated gas loss , which is estimated to be 1.05TBW ($1.01k_o - 1.04\ k_d$) (Schoeller, 1988). The amount of ^{18}O that leaves the body as CO_2 (kCO_2) would represent the amount of CO_2 produced by metabolism of food substrates (oxidation of fat, protein and carbohydrate), since the body only produces CO_2 by this route (Lifson, Gordon, and McClintock, 1955). The TEE can then be calculated by using an indirect calorimetry equation , if food quotient (FQ) is known (Weir, 1949):

$$\text{TEE (kcal/day)} = 22.4 \times (1.106 \times kCO_2 + 3.941 \times kVO_2)$$

where kVO_2 is = kCO_2/FQ. FQ is the respiratory quotient (the ratio of CO_2 produced to O^2 used) of a food when it is being consumed. It is determined by burning the food in an atmosphere of pure oxygen and has been set as a constant value of 0.85 for convenience (Weir, 1949).

Validation against near-continuous indirect calorimetry and weighed food intake has demonstrated that the DLW method is accurate to 1-2% with a coefficient of variation of 2-12% (Schoeller, 1988).

The DLW doses were prepared by Energetics Group, Zoology Department, University of Aberdeen, UK. Each contained 120ml of the dose (made up of 10% $^{18}0$ and 5% deuterium) which was pre-measured according to individual subject's body weight. These DLW doses were sent to The Queen's Medical Research Institute, Edinburgh, UK, via courier (at room temperature) in sealed glass bottles in ready-to-drink form. Each bottle was labelled with a specific reference number.

A subgroup of subjects (who attended the AMC between July and December 2010) were invited to participate in the study. Those who agreed were asked to fast overnight and attend the clinic in the morning for the dosing. At the clinic, a baseline urine sample was collected and body weight measured using SECA 959 chair weighing scale (SECA Ltd., Birmingham, UK), as detailed in Section 2.4.3. After the reference number of the DLW dose recorded, each subject was asked to drink it until finished using a drinking straw. The bottle was then fully refilled with drinking water and the subject was asked to drink all of this too to ensure complete administration of the isotopes. Subjects were then asked to collect one urine sample on day 1, day 5, day 10 and day 14 after the doubly labelled water was consumed using the urine tubes provided. They were asked to try to collect the sample at the same time each day e.g. the second urine in the morning. They were also asked to avoid the first urine void of the day and ideally collect the sample half an hour later. Subjects were reminded to fill in the time of the sampling on the tube label before collecting the sample.

The urine sample was only filled to about half of the urine tube (~25ml) and tightly capped to avoid leakage, evaporation or contamination. Samples were kept at room temperature for collection on the same day. Otherwise (e.g. for weekend sample) they were placed in containers provided and kept in the freezer until picked up on the next working day. A written instruction sheet (refer Appendix T) was given and subjects were briefed about the day and date for sampling and were asked to adhere to this as strictly as possible. Subjects were also reminded about sample collection by a text message sent on the evening before and on the morning when sampling was due.

The samples collected from volunteers were kept double-bagged and upright in -20 Celsius freezer. Samples were packed with frozen gel coolants and sent by courier to the Energetics Group, Zoology Department, University of Aberdeen, UK for analysis.

2.7 Data analysis

2.7.1 Scottish Collaborative Group Food Frequency Questionnaire

Questionnaires were checked by the researcher after completion. If any data were missing, the subject was approached to address this at the clinic. However, if this was not possible, or where there were between 1 and 10 missing answers, default answers for missing information (SCG-FFQ administrator's standard operating procedures, Scottish Collaborative Group, University of Aberdeen, UK) were used. Thus, if 'R' (Rarely) was circled together with a number for the 'Measure per day', the number was crossed out leaving the R alone. If 'M' (Monthly) was circled together with a number of days per week: if it was M and 1, 2, or 3 – the number was just crossed out. If it was M and 4, 5, 6 or 7 – the M and the number were crossed out and number 1 (for Once a week) was circled. If there were more than 10 missing answers, the questionnaire was excluded.

Data from completed questionnaires were entered into a Microsoft Access entry package provided by the SCG-FFQ administrator (Scottish Collaborative Group, University of Aberdeen, UK). Data entry was double checked by someone not involved with the original data entry in a random sample of approximately 10 percent of the entered questionnaires. A test file was then created and exported to the administrator. The results included total energy intake (in both kilocalories and kilojoules) and 38 other nutrients, as listed in Appendix U.

2.7.2 Food diary

FD was checked after completion. If there was any information not complete or not understood, this was addressed with the subject. Data from FD were analysed by using dietary analysis software, Windiets Standard (Windiets, Robert Gordon University, UK) (refer Appendix U for detailed list of nutrients analyzed).

2.7.3 General Nutrition Knowledge Questionnaire

The GNKQ was analyzed manually following the answer scheme as provided by the questionnaire developer (Parmenter and Wardle, 1999). Each correct answer was given one point and wrong answer was given zero. Section I (Dietary Recommendations) carries a maximum score of 11 points, Section II (Sources of Foods/Nutrients) 69 points, Section III (Choosing Everyday Foods) 10 points, and Section IV (Diet-Disease Relationships) 20 points. The maximum score for the whole questionnaire is 110 points.

2.7.4 Council on Nutrition Appetite Questionnaire

The CNAQ was analyzed manually following the instructions provided in a publication that discussed the use of this questionnaire (Wilson et al, 2005). Each question contains 5 answer options (‘a’ to ‘e’) and each of this option corresponds to the following numerical scale: a=1, b=2, c=3, d=4, and e=5 scores. The sum of the scores represents the CNAQ score.

2.7.5 Dutch Eating Behaviour Questionnaire

The DEBQ was analyzed manually following the instructions provided in a publication that discussed the use of this questionnaire (van Strien et al, 1986). Each item in the DEBQ which is measured on a 5-point Likert scale corresponds to the following numerical score: Never=1, Seldom=2, Sometimes=3, Often=4, and Very Often=5). The scores were totalled for each restraint eating, emotional eating, and externally-induced eating section and divided by the total number of items for each scale.

2.7.6 Pregnancy Physical Activity Questionnaire

The PPAQ was analyzed manually following instructions provided by the main developer of the questionnaire (Chasan-Taber, 2004). Each question asked in the PPAQ represents an activity. To arrive at a measure of average weekly energy expenditure in metabolic equivalent (MET)-hours per week for each activity, the duration of time spent (calculated from the duration scores as selected by the subject) is multiplied by its intensity (which is provided in the instruction manual). To calculate the duration, each duration score corresponds to a certain duration category. These values are then multiplied by 7 days per week, if the original duration scores are in daily form, or left as they are, if they are already in the weekly form. To calculate the intensity, two references are used; field-based measurements (Chasan-Taber et al, 2007) are used to represent activity intensity for walking and light- to moderate-intensity household tasks, and Compendium-based MET values (Ainsworth et al, 2000) are used to estimate the intensity of the remainder of activities in the PPAQ. For specific duration categories and intensity (MET values) assigned to each question, please refer to Appendix V. The total activity is calculated as the sum of (duration X intensity) for all the questions. The total MET-hours per week were also calculated for different categories of activities such as based on different intensity levels (sedentary, light-, moderate- and vigorous activities) and different types of activities (household/caregiving, occupational, sport/exercise). For analysis purposes, the results were divided by 7 to obtain MET-hours per day.

2.7.7 Accelerometry

After the accelerometers were collected from study participants, data were retrieved by using the 'Read' function on the *Actical* software, and then downloaded into the computer by using the *Actireader* hardware. Since the accelerometer converts movement (activity counts) into energy units (calories), the data were displayed as activity energy expenditure which includes time, activity, hourly and daily sum of energy expenditure.

2.7.8 Doubly labelled water

The urine samples collected in the DLW study were sent for analysis to the Energetics Group, Zoology Department, University of Aberdeen, UK. Briefly, 100μl of urine sample was vacuum distilled and water from the resulting distillate was used to produce CO_2 and H_2 (Speakman and Krol, 2005, Speakman et al, 1990). The isotope ratios $^{18}0:^{16}O$ and $^{2}H:^{1}H$ were analyzed by using gas source isotope ratio mass spectrometry (Optima, Micromass IRMS and Isochrome μG, Manchester, UK). Samples were run alongside three lab standards for each isotope (calibrated to International Standards) to correct delta values to parts per million (ppm). Isotope enrichments were converted to values of total energy expenditure per 24 hours using a single pool model (Speakman and Krol, 2005, Speakman et al, 1990).

2.8 Statistical analyses

Normal distribution of data was assessed visually using Q-Q plots and histograms, and using Kolmogorov-Smirnov or Shapiro-Wilk test (for $n<50$). Data which were not normally distributed were normalized using natural log transformation.

Comparisons between obese and lean groups were analysed by using independent t-test. Comparison of more than 3 groups were done using analysis of variance (ANOVA) test. Categorical data were tested by using chi square or Fisher's exact test. Comparison between early and late pregnancy in women with available data for both time points was analysed by using paired t-test. Correlations were assessed by using Pearson correlation coefficient.

Since there were significance differences in demographic characteristics i.e. age, parity, ethnicity, and DEPCAT status, between obese and lean study participants (refer Appendix C), all results (except for paired data) were adjusted for these potential confounding factors, using linear regression analysis. Nutrients data were also adjusted for total energy intake using regression residual method.

The significance level was set at 5% and all statistical analyses were performed using SPSS version 14.0 (SPSS Inc., Chicago, IL, USA).

Statistical analyses are presented in further detail in each individual chapter.

2.8.1 Statistical power calculation

Post-hoc power calculation was carried out using the Sampsize version 0.6 program for comparative study of means (Glaziou,2003). This was done using mean and standard deviation values, and sample size for each group in early and late pregnancy for total calories (kcal/day), total physical activity (MET-hours/day), accelerometry average activity counts/minute, and total energy expenditure as measured by the doubly-labelled water technique, with significance level set at 5%. The power obtained for each study was as detailed in Table 2.1.

Table 2.1
Post-hoc statistical power calculation for each study

Assessment		Obese Group		Lean Group		Statistical power
Total energy intake (kcal/day)	Early pregnancy	Mean	2,652	Mean	2,470	33%
		SD	1,206	SD	728	
		n	139	n	80	
	Late pregnancy	Mean	2,336	Mean	2,430	17%
		SD	911	SD	662	
		n	136	n	69	
Total physical activity (MET-hrs/day)	Early pregnancy	Mean	28.2	Mean	22.4	84%
		SD	18.4	SD	13.1	
		n	131	n	83	
	Late pregnancy	Mean	26.8	Mean	22.0	67%
		SD	15.9	SD	11.3	
		n	95	n	51	
Average activity counts (counts/min/day)	Early pregnancy	Mean	187	Mean	255	69%
		SD	58	SD	86	
		n	14	n	14	
	Late pregnancy	Mean	185	Mean	248	70%
		SD	68	SD	86	
		n	14	n	14	
Total energy expenditure (kcal/day) in obese group	Early pregnancy	Mean	3,264			9%
		SD	379			
		n	4			
	Late pregnancy	Mean	3,122			
		SD	376			
		n	4			

CHAPTER 3

Validation of Scottish Collaborative Group Food Frequency Questionnaire in severely obese pregnant women

Chapter 3

3.1 Introduction

Food frequency questionnaires (FFQ) are popular instruments for assessing dietary intakes in epidemiological studies, mostly because they are easy to administer, are relatively inexpensive, and do not place a heavy burden on either the subjects or the research staff. This tool also allows collection of information on usual or average food intake over an extended period, thus reflecting habitual intake compared to just a snapshot of a few days' diet (Wakai, 2009, Cade et al, 2002). For these reasons, the FFQ has been extensively used for epidemiological purposes, including in studies investigating the nutritional status of pregnant women (Hure et al, 2009, Mouratidou et al, 2006a, Martindale et al, 2005, Moore et al, 2004, Mathews, Yudkin and Neil, 1999, Rogers and Emmett, 1997, Godfrey et al, 1996).

There are some limitations in the use of the FFQ to estimate food intake. This method relies heavily on an individuals' ability to recall the food they usually eat and conceptualize the portion sizes. It is also susceptible to measurement errors that are associated with the use of any dietary assessment instrument (Kipnis et al, 2002, Cade et al, 2002). Because dietary habits vary greatly among individuals, a FFQ intended for use in a study must be tailored for use with specific population to ensure the accuracy of information obtained (Wakai, 2009). It is therefore essential that the validity of a FFQ is assessed in a subset of the study population to evaluate its ability in measuring what it is designed to measure, and its suitability for use in the target population (Cade et al, 2002).

There is no consensus in the literature on the best method for assessing the validity of a FFQ. Ideally, FFQ validation should be done against objective biological measures of energy (via doubly-labelled water technique) or of other biomarkers such as nitrogen, sodium, vitamin C and fat-soluble vitamins (Cade et al, 2004). However, the costs and resources involved to carry out these techniques limit its use. A systematic review showed that 75% of studies calibrated an FFQ against another dietary instrument (Cade et al, 2002). A food record/diary, with or without food weighing, is commonly used as a reference method with which to validate the FFQ because the food diary (FD) provides a more detailed and quantitative estimate of nutrient intake, is not influenced by recall bias, and is likely to have the smallest correlated errors among the dietary assessment instruments (Cade et al, 2002). This technique has been used previously to determine the reliability and validity of FFQ in general pregnant women populations (Brantsaeter et al, 2008, Errkola et al, 2001, Robinson et al, 1996). Even though different methods of measuring dietary intake are affected by different sources of bias, validity of certain method can be assessed relative to another dietary assessment method. The use of various statistical methods is highly recommended to give credence to the validity values, based on consistency between results (Masson et al, 2003, Cade et al, 2002).

Maternal nutrition plays a very important role in determining the health of both mother and infant, and the use of a valid instrument to assess dietary intake in pregnancy is crucial. Even though the Scottish Collaborative Group FFQ (SCG-FFQ) used here has been extensively used in Scottish pregnant women populations (Martindale et al, 2005), its validity and suitability for use in pregnancy associated with obesity has never been tested, hence the need for this validation study.

3.2 Aim

The aim of the work described in the present chapter was to compare intakes of total calories and nutrients assessed by using the SCG-FFQ against a 4-day FD (reference method), in order to assess the relative validity of the SCG-FFQ in estimating the food intake of severely obese pregnant women who participated in the Energy Balance in Pregnancy (EBIP) study. A similar assessment was also carried out in lean pregnant controls.

3.3 Methods

3.3.1 Study design

This was a validation study where each subject was asked to complete both the SCG-FFQ and FD. Energy and nutrient intakes from the SCG-FFQ were compared against the FD in order to assess its validity.

3.3.2 Ethical approval

The study protocol was approved by the Lothian Research Ethics Committee and written informed consent was obtained from all participants.

3.3.3 Subjects recruitment

A subgroup of severely obese and lean pregnant women who participated in the Energy Balance in Pregnancy (EBIP) Study and had completed the SCG-FFQ, were invited to take part in this validation study. Participants for the EBIP Study were recruited from an ongoing cohort (Hormones and Inflammation in Pregnancy, HIP) study of obesity during pregnancy at the Antenatal Metabolic Clinic.

3.3.4 Scottish Collaborative Group Food Frequency Questionnaire

The semi-quantitative SCG-FFQ version 6.6 (Scottish Collaborative Group, University of Aberdeen, UK) was used to measure dietary intake in the study population (as described in detail in Section 2.5.1). All subjects completed the SCG-FFQ prior to the FD.

3.3.5 Food Diary

The women were asked to keep a FD (Food and Drink Diary for Adults, University of Aberdeen) for a period of 4 days (3 week days and 1 weekend day), as detailed in Section 2.5.2.

3.3.6 Data analyses

The data from SCG-FFQ were sent to its administrator (Scottish Collaborative Group, University of Aberdeen, UK) for nutrient analyses (as detailed in Section 2.7.1)

FD was analysed by using dietary analysis software, Windiets Standard (Windiets, Robert Gordon University, UK) as detailed in Section 2.7.2.

3.3.7 Statistical methods

Normal distribution of data was assessed visually using histograms and Q-Q plots, and by using Shapiro-Wilk test. Nutrient intakes were not normally distributed and were normalised by using natural log transformation.

To minimize the effect of measurement errors such misreporting of energy intake (which could affect the absolute intakes of nutrients), nutrient intakes were adjusted for total energy intake using the residual method. This was done by adding the residual (the difference between the observed nutrient values for each subject and the values predicted by regression equation) to the nutrient intake that corresponds with the mean total energy intake of the study population (Willet and Stampfer, 1986). Nutrient intakes from dietary supplements were not included in any of the analyses.

The differences between the nutrient intakes estimated from SCG-FFQ and FD were assessed by using paired t-test. The relative agreement between the SCG-FFQ and FD was assessed by Spearman Rank correlation (non-parametric, on raw data) and Pearson correlation (parametric, on normalised data) on both measured and energy-adjusted values. The relationship between these two dietary methods was also examined by cross-classification. Subjects were classified into thirds of intake by each dietary method. Percentages of subjects correctly categorized into same group by both methods and grossly misclassified into opposite groups were then calculated. The Cohen's weighted kappa (K_w)

value was determined for each nutrient as another measure of relative validity (Norman and Streiner, 2008).

The significance level was set at 5% and all statistical analyses were performed using SPSS version 14.0 (SPSS Inc., Chicago, IL, USA). Data were presented as median (25^{th} and 75^{th} percentile) unless stated otherwise.

3.4 Results

Out of 99 women (60 obese and 39 lean) who were invited, 48 obese and 37 lean pregnant women agreed to take part in the study; of these, 31 obese (52%) and 32 lean (82%) completed the study. 4 diaries (obese) were believed to be lost in the mail, 2 women (lean) withdrew from the study, 9 obese and 1 lean failed to complete the diaries after reminder calls, and 4 obese and 2 lean were not able to be contacted after initially agreeing to take part in the study.

Table 3.1 shows the demographic characteristics of participants. Obese and lean women were of similar age and parity, and all participants were Caucasian. However, obese women had significantly lower Deprivation Category (DEPCAT) status compared to lean. Overall, both obese and lean participants who were included in this study were found to be largely representative of the larger HIP cohort. However, the obese participants were found to be slightly (~3 years) but significantly older, than the rest of obese participants who did not take part in this study (refer Appendix D).

Table 3.1

Demographic characteristics of participants who completed the SCG-FFQ validation study

		Obese (n=31)		Lean (n=32)		
		Mean	(Range or %)	Mean	(Range or %)	*P value*
Age (years)		33.6	(21.0 – 44.5)	33.1	(21.1 – 42.3)	*P=0.672*[‡]
BMI at booking (kg/m^2)		43.3	(38.6 – 50.2)	22.8	(19.9 – 25.4)	*P=0.001*[‡]
Parity	Primiparous	18	(58.1%)	19	(59.4%)	*P=0.853*[†]
	Multiparous	13	(41.9%)	13	(40.6%)	
Ethnicity	Caucasian	31	(100.0%)	32	(100.0%)	
DEPCAT status	Low	5	(16.1%)	1	(9.5%)	*P=0.001*[†]
	Middle	25	(80.6%)	19	(69.8%)	
	High	1	(3.3%)	12	(20.7%)	

[‡] Tested using independent t-test; [†] Tested using chi square test; DEPCAT – Deprivation Category

Absolute Agreement

The measured intakes of nutrients estimated by the FFQ and FD for obese and lean groups are shown in Tables 3.2a and 3.2b. All nutrients were reported to be significantly higher in FFQ as compared to FD in both groups, with the exception of niacin and vitamin C. Intakes of niacin were estimated to be lower from FFQ as compared to FD in both groups. Vitamin C intake was similar from FFQ and FD in the obese group.

Relative Agreement

Tables 3.3a and 3.3b showed the Pearson and Spearman correlation coefficients between both crude and energy-adjusted nutrient intakes estimated by FFQ and FD, for obese and lean groups respectively. For energy-adjusted data, average Pearson correlation coefficients were 0.345 (range -0.186 to 0.710) in obese; and 0.334 (range -0.252 to 0.743) in lean. There was a significant correlation for total energy intake between FFQ and FD in the lean group, but this was not seen in obese. In terms of macronutrients, in obese, there was a significant correlation for fat intake, which did not persist when adjusted for total energy intake. On the other hand, correlation for protein intake became significant after energy adjustment. In lean, there was a significant correlation between FFQ and FD for protein, but this was no longer significant after adjustment for total energy intake.

A correlation coefficient between dietary assessment methods of greater than 0.5 has been suggested as acceptable in validation studies of FFQ (Brunner et al, 2001). In this study, energy-unadjusted Pearson correlation coefficients >0.5 were found for 1 nutrient (dietary cholesterol) in obese and 15 nutrients in lean. After energy adjustment, Pearson correlation coefficients >0.5 were found for 5 nutrients in obese and 8 nutrients in lean. In obese, significant correlation coefficients were observed for 9 nutrients including saturated fatty acids (SFA), dietary cholesterol, sugars, calcium, phosphorus, iodine, and vitamins B6, B12, and C, both before and after adjustment for total energy. In lean, this was observed for a total of 18 nutrients (SFA, polyunsaturated fatty acids (PUFA), dietary cholesterol, fibre, potassium, calcium, phosphorus, zinc, manganese, iodine, beta-carotene, riboflavin, niacin, biotin, and vitamins B6, B9 and C). Correlation coefficients were lowest for fibre and selenium in obese, and carbohydrate and copper in lean.

Table 3.2a

Median (interquartile range) crude daily nutrient intakes from the FFQ and FD (obese group)

Nutrient	FFQ		FD		*P value* [1]	*P value* [2]
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})		
Energy (kcal)	2426	(2019, 2690)	1563	(1209, 1783)	*<0.001*	
Protein (g)	103.3	(78.8, 124.1)	63.0	(50.7, 72.2)	*<0.001*	*0.655*
Fat (g)	97.9	(73.2, 119.8)	61.6	(48.4, 77.0)	*<0.001*	*0.827*
Carbohydrate (g)	287.8	(241.6, 367.0)	198.7	(149.2, 235.4)	*<0.001*	*0.720*
SFA (g)	37.2	(27.1, 47.6)	23.6	(16.5, 27.6)	*<0.001*	*0.664*
MUFA (g)	34.0	(24.8, 40.4)	20.6	(16.1, 24.8)	*<0.001*	*0.588*
PUFA (g)	16.5	(13.8, 18.6)	10.5	(8.5, 14.3)	*0.004*	*0.168*
Cholesterol (mg)	300	(215, 420)	185	(133, 222)	*<0.001*	*0.466*
Sugars (g)	134.0	(113.8, 167.0)	80.3	(62.0, 101.4)	*<0.001*	*0.105*
Starch (g)	138.0	(121.0, 178.0)	112.1	(97.0, 132.9)	*0.001*	*0.362*
Fibre (g)	22.0	(16.1, 28.3)	3.3	(2.7, 4.3)	*<0.001*	*1.000*
Sodium (mg)	3222	(2448, 3972)	2381	(1884, 2782)	*0.002*	*0.293*
Potassium (mg)	3957	(3300, 5166)	2371	(1860, 2834)	*<0.001*	*0.686*
Calcium (mg)	1197	(922, 1596)	776	(584, 945)	*<0.001*	*0.735*
Magnesium (mg)	416	(338, 490)	211	(152, 268)	*<0.001*	*0.279*
Phosphorus (mg)	1783	(1448, 2178)	1075	(890, 1230)	*<0.001*	*0.558*
Iron (mg)	14.17	(11.54, 17.34)	8.40	(6.05, 11.25)	*<0.001*	*0.504*
Copper (mg)	2.83	(2.36, 3.47)	0.81	(0.53, 1.11)	*<0.001*	*0.854*
Zinc (mg)	12.40	(9.50, 15.40)	6.60	(5.65, 8.30)	*<0.001*	*0.671*
Chloride (mg)	4826	(3788, 6061)	3575	(2772, 4036)	*0.002*	*0.165*
Manganese (mg)	4.30	(3.30, 4.95)	2.08	(1.51, 2.71)	*<0.001*	*0.583*
Selenium (µg)	67.0	(47.0, 80.0)	34.0	(27.5, 47.5)	*<0.001*	*0.570*
Iodine (µg)	254	(182, 316)	122	(96, 152)	*<0.001*	*0.692*
Retinol (µg)	325	(236, 426)	224	(171, 326)	*0.012*	*0.690*
B-carotene equivalent (µg)	3381	(2393, 7336)	1093	(826, 1656)	*<0.001*	*0.800*
Vitamin D (µg)	4.05	(2.61, 4.77)	1.79	(0.72, 2.54)	*<0.001*	*0.820*
Vitamin E (mg)	11.98	(9.03, 15.33)	7.11	(5.07, 9.03)	*<0.001*	*0.800*
Thiamine (mg)	1.97	(1.53, 2.40)	1.36	(1.11, 1.59)	*<0.001*	*0.145*
Riboflavin (mg)	2.08	(1.60, 2.89)	1.30	(1.01, 1.61)	*<0.001*	*0.970*
Niacin (mg)	24.50	(18.55, 29.85)	27.80	(23.65, 34.80)	*0.011*	*0.509*
Vitamin B6 (mg)	2.58	(2.03, 3.30)	1.59	(1.40, 2.12)	*<0.001*	*0.155*
Vitamin B12 (µg)	6.80	(5.05, 8.80)	3.89	(2.78, 5.43)	*<0.001*	*0.541*
Folic acid (µg)	323	(240, 398)	204	(154, 231)	*<0.001*	*0.390*
Pantothenic acid (mg)	6.53	(5.20, 7.91)	3.60	(3.15, 5.00)	*<0.001*	*0.807*
Biotin (µg)	46.5	(36.7, 52.4)	20.3	(16.4, 26.5)	*<0.001*	*0.916*
Vitamin C (mg)	150.0	(116.5, 229.5)	99.4	(49.5, 173.2)	*0.197*	*0.907*

FFQ – Food frequency questionnaire; FD – food diary; P_{25} – 25th percentile, P_{75} – 75th percentile;
SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids;
PUFA – Polyunsaturated fatty acids
P value [1] – log-transformed, crude intakes (paired t-test)
P value [2] – log-transformed, energy-adjusted (paired t-test)

Table 3.2b

Median (interquartile range) crude daily nutrient intakes from the FFQ and FD (lean group)

Nutrient	FFQ		FD		*P value* [1]	*P value* [2]
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})		
Energy (kcal)	2489	(2010, 3020)	1752	(1473, 1942)	*<0.001*	-
Protein (g)	92.6	(74.2, 122.0)	65.8	(56.2, 74.6)	*<0.001*	*0.782*
Fat (g)	95.4	(72.4, 129.0)	66.1	(54.9, 81.7)	*<0.001*	*0.873*
Carbohydrate (g)	334.9	(259.4, 358.4)	222.8	(188.6, 263.0)	*<0.001*	*0.819*
SFA (g)	36.2	(27.4, 50.4)	22.5	(19.8, 28.9)	*<0.001*	*0.651*
MUFA (g)	33.1	(25.0, 43.3)	21.8	(17.6, 25.0)	*<0.001*	*0.528*
PUFA (g)	17.5	(13.0, 21.0)	12.0	(9.3, 13.9)	*<0.001*	*0.072*
Cholesterol (mg)	321	(205, 388)	210	(144, 253)	*<0.001*	*0.364*
Sugars (g)	144.1	(114.1, 188.2)	107.5	(80.4, 123.4)	*<0.001*	*0.116*
Starch (g)	170.5	(130.2, 194.2)	117.8	(96.8, 140.9)	*<0.001*	*0.529*
Fibre (g)	24.8	(19.4, 30.0)	5.1	(3.0, 6.5)	*<0.001*	*0.952*
Sodium (mg)	3299	(2440, 4433)	2336	(2005, 2748)	*<0.001*	*0.302*
Potassium (mg)	4294	(3420, 4928)	2371	(2104, 2994)	*<0.001*	*0.844*
Calcium (mg)	1372	(1035, 1609)	831	(788, 1110)	*<0.001*	*0.715*
Magnesium (mg)	468	(389, 539)	239	(207, 301)	*<0.001*	*0.417*
Phosphorus (mg)	1931	(1485, 2343)	1169	(1046, 1312)	*<0.001*	*0.481*
Iron (mg)	17.68	(13.70, 21.34)	10.45	(8.55, 12.13)	*<0.001*	*0.630*
Copper (mg)	3.27	(2.76, 4.36)	1.06	(0.86, 1.25)	*<0.001*	*0.856*
Zinc (mg)	12.55	(8.78, 15.25)	7.30	(6.28, 8.90)	*<0.001*	*0.678*
Chloride (mg)	4986	(3667, 6549)	3362	(2877, 3810)	*<0.001*	*0.161*
Manganese (mg)	4.40	(3.98, 6.33)	2.66	(2.26, 3.32)	*<0.001*	*0.625*
Selenium (µg)	67	(50, 82)	36.5	(26.8, 48.2)	*<0.001*	*0.490*
Iodine (µg)	276	(193, 368)	152	(112, 174)	*<0.001*	*0.746*
Retinol (µg)	339	(252, 506)	297	(209, 345)	*0.028*	*0.592*
B-carotene equivalent (µg)	39251	(2890, 8520)	1608	(951, 2088)	*<0.001*	*0.699*
Vitamin D (µg)	4.68	(2.88, 6.53)	2.24	(1.17, 3.53)	*<0.001*	*0.781*
Vitamin E (mg)	13.69	(9.38, 15.76)	8.51	(6.63, 10.71)	*<0.001*	*0.740*
Thiamine (mg)	2.19	(1.72, 2.48)	1.43	(1.19, 1.55)	*<0.001*	*0.242*
Riboflavin (mg)	2.46	(2.03, 2.87)	1.66	(1.41, 1.82)	*<0.001*	*0.970*
Niacin (mg)	24.55	(19.73, 28.15)	29.90	(26.05, 34.98)	*<0.001*	*0.405*
Vitamin B6 (mg)	2.84	(2.11, 3.37)	1.53	(1.32, 1.81)	*<0.001*	*0.193*
Vitamin B12 (µg)	7.35	(4.80, 9.83)	3.65	(2.71, 5.04)	*<0.001*	*0.594*
Folic acid (µg)	398	(285, 450)	230	(182, 262)	*<0.001*	*0.587*
Pantothenic acid (mg)	7.07	(5.27, 8.46)	4.20	(3.58, 5.13)	*<0.001*	*0.840*
Biotin (µg)	50.0	(36.5, 61.4)	26.1	(22.2, 33.7)	*<0.001*	*0.962*
Vitamin C (mg)	154.5	(116.0, 221.2)	108.5	(77.6, 149.5)	*0.001*	*0.970*

FFQ – Food frequency questionnaire; FD – food diary; P_{25} – 25th percentile, P_{75} – 75th percentile; SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids;
PUFA – Polyunsaturated fatty acids
P value [1] – log-transformed, crude intakes (paired t-test)
P value [2] – log-transformed, energy-adjusted (paired t-test)

Table 3.3a

Pearson *r* and Spearman r_s correlation coefficients between FFQ and FD in obese group (n=31)

Nutrient	Pearson†		Spearman	
	r_{crude}	$r_{energy\text{-}adjusted}$	r^s_{crude}	$r^s_{energy\text{-}adjusted}$
Energy	0.284		0.334	
Protein	0.192	0.354*	0.250	0.295
Fat	0.378*	0.115	0.487**	-0.008
Carbohydrate	0.229	-0.027	0.265	0.197
SFA	0.498**	0.447**	0.519**	0.302
MUFA	0.426*	0.184	0.521**	0.086
PUFA	0.186	0.161	0.201	0.146
Cholesterol	0.545**	0.457**	0.415*	0.222
Sugars	0.352*	0.575**	0.438*	0.252
Starch	0.293	0.417*	0.390*	0.212
Fibre	-0.089	0.044	-0.072	-0.183
Sodium	0.331	0.180	0.513**	0.358*
Potassium	0.287	0.703**	0.303	0.538**
Calcium	0.410*	0.507**	0.447*	0.429*
Magnesium	0.251	0.413*	0.295	0.431*
Phosphorus	0.384*	0.408*	0.445*	0.588**
Iron	0.104	0.417*	0.324	0.327
Copper	0.083	-0.186	0.152	-0.135
Zinc	0.269	0.413*	0.370*	0.448*
Chloride	0.368*	0.211	0.511**	0.426*
Manganese	0.313	0.710**	0.374*	0.535**
Selenium	0.007	0.035	0.150	0.060
Iodine	0.485**	0.531**	0.481**	0.418*
Retinol	0.444*	0.313	0.495**	0.064
B-carotene equivalent	0.185	0.238	0.214	0.130
Vitamin D	0.171	0.155	0.028	0.106
Vitamin E	0.031	0.393*	0.045	0.185
Thiamine	0.235	0.506**	0.190	0.340
Riboflavin	0.320	0.466**	0.269	0.468**
Niacin	0.085	0.200	0.067	0.146
Vitamin B6	0.383*	0.496**	0.302	0.482**
Vitamin B12	0.457*	0.513**	0.304	0.290
Folic acid	0.260	0.418*	0.230	0.462**
Pantothenic acid	0.206	0.343	0.236	0.452*
Biotin	0.358*	0.341	0.373*	0.443*
Vitamin C	0.400*	0.688**	0.516**	0.523**

SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids;
PUFA – Polyunsaturated fatty acids
† For log-transformed nutrient intakes
* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Table 3.3b

Pearson *r* and Spearman r_s correlation coefficients between FFQ and FD in lean group (n=32)

Nutrient	Pearson†		Spearman	
	r_{crude}	$r_{energy\text{-}adjusted}$	r^s_{crude}	$r^s_{energy\text{-}adjusted}$
Energy	0.462**		0.510**	
Protein	0.491**	0.114	0.616***	0.196
Fat	0.295	0.045	0.442*	-0.016
Carbohydrate	0.053	-0.085	0.312	0.074
SFA	0.598***	0.527**	0.664***	0.356*
MUFA	0.388*	0.311	0.379*	0.221
PUFA	0.521**	0.398**	0.575**	0.410*
Cholesterol	0.663***	0.743**	0.498**	0.459**
Sugars	0.082	0.207	0.146	0.268
Starch	0.506**	0.151	0.420*	0.200
Fibre	0.534**	0.377*	0.400*	0.294
Sodium	0.397*	0.241	0.385*	0.215
Potassium	0.385*	0.515**	0.452**	0.493**
Calcium	0.589***	0.370*	0.602***	0.318
Magnesium	0.393*	0.185	0.340	0.294
Phosphorus	0.556**	0.452**	0.522**	0.345
Iron	0.593***	0.234	0.466**	0.263
Copper	0.044	-0.252	0.126	-0.078
Zinc	0.656***	0.398*	0.635***	0.428*
Chloride	0.450*	0.270	0.393*	0.203
Manganese	0.633***	0.681**	0.611***	0.567**
Selenium	0.224	0.294	0.253	0.282
Iodine	0.527**	0.432*	0.521**	0.375*
Retinol	0.251	0.320	0.441*	0.433*
B-carotene equivalent	0.434*	0.404*	0.329	0.274
Vitamin D	0.165	0.253	0.217	0.208
Vitamin E	0.523**	0.310	0.480**	0.284
Thiamine	0.457**	0.335	0.380*	0.216
Riboflavin	0.519**	0.374*	0.370*	0.329
Niacin	0.530**	0.563**	0.507**	0.255
Vitamin B6	0.487**	0.419*	0.499**	0.454**
Vitamin B12	0.391*	0.337	0.243	0.141
Folic acid	0.388*	0.333	0.360*	0.229
Pantothenic acid	0.503**	0.415*	0.433*	0.173
Biotin	0.481**	0.426*	0.437*	0.320
Vitamin C	0.334	0.447*	0.367*	0.367*

SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids;
PUFA – Polyunsaturated fatty acids
† For log-transformed nutrient intakes
* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level
*** Correlation is significant at the 0.001 level

The ability of the FFQ to rank individuals was determined by cross-classification. Percentages of participants categorized into the same or opposite thirds of intake and weighted kappa (K_w) value for each nutrient are shown in Table 3.4. On average, about 48% of participants of both groups were correctly classified whereas 13% of obese and 10% of lean were grossly misclassified between the two methods. K_w value for total energy was lower in obese as compared to lean. The highest K_w value for macronutrients was for fat in obese and protein in lean. In general, K_w values <0 show poor agreement; 0-0.2 slight agreement; 0.2-0.4 fair agreement; 0.4-0.6 moderate agreement and 0.6-0.8 substantial agreement (Landis and Koch, 1977). K_w values were found to have poor agreement for fibre in obese (in agreement with cross-classification and correlation), and slight agreement for copper, selenium, and vitamin B12 in lean. However, substantial agreement was shown for fat, SFA, PUFA, chloride, iodine, and retinol, in obese, and protein, SFA, PUFA, cholesterol, calcium, phosphorus, iron, zinc, manganese, iodine, retinol, niacin, and vitamin B6, in lean.

Table 3.4
Percentages of subjects classified into the same and opposite thirds of intake and weighted kappa (K_w)

	Obese (n=31)				Lean (n=32)			
	Percentages classified in				Percentages classified in			
Nutrient	Same third	Opposite third	K_w	*P value*	Same third	Opposite third	K_w	*P value*
Energy	45	10	0.468	*0.044*	50	12	0.560	*0.013*
Protein	42	10	0.471	*0.043*	53	3	0.743	*<0.001*
Fat	61	6	0.687	*0.001*	50	12	0.559	*0.013*
Carbohydrate	52	19	0.373	*0.103*	44	16	0.321	*0.143*
SFA	64	3	0.789	*<0.001*	53	3	0.744	*<0.001*
MUFA	55	3	0.721	*<0.001*	38	16	0.361	*0.109*
PUFA	48	6	0.552	*0.016*	50	9	0.634	*0.003*
Cholesterol	45	13	0.483	*0.038*	50	6	0.674	*0.001*
Sugars	48	10	0.520	*0.024*	31	16	0.282	*0.180*
Starch	58	13	0.527	*0.022*	47	12	0.498	*0.030*
Fibre	26	13	-0.039	*0.541*	50	12	0.548	*0.015*
Sodium	48	10	0.560	*0.014*	41	6	0.589	*0.008*
Potassium	58	16	0.498	*0.032*	47	9	0.550	*0.015*
Calcium	45	13	0.508	*0.028*	56	0	0.775	*<0.001*
Magnesium	42	13	0.409	*0.078*	53	9	0.578	*0.009*
Phosphorus	55	13	0.586	*0.009*	47	3	0.675	*0.001*
Iron	32	13	0.269	*0.198*	50	6	0.626	*0.004*
Copper	45	19	0.201	*0.272*	34	16	0.003	*0.496*
Zinc	45	13	0.465	*0.046*	62	3	0.765	*<0.001*
Chloride	55	6	0.713	*<0.001*	41	9	0.471	*0.041*
Manganese	61	13	0.539	*0.019*	56	22	0.645	*0.003*
Selenium	55	13	0.481	*0.039*	38	22	0.163	*0.311*
Iodine	52	6	0.636	*0.004*	53	9	0.649	*0.002*
Retinol	61	10	0.673	*0.002*	56	3	0.660	*0.002*
B-carotene equivalent	35	13	0.306	*0.161*	44	12	0.467	*0.043*
Vitamin D	39	16	0.093	*0.395*	47	16	0.426	*0.064*
Vitamin E	35	16	0.247	*0.221*	41	12	0.435	*0.059*
Thiamine	48	22	0.226	*0.244*	44	9	0.500	*0.029*
Riboflavin	48	16	0.409	*0.078*	41	9	0.421	*0.067*
Niacin	48	39	0.250	*0.217*	53	6	0.656	*0.002*
Vitamin B6	58	13	0.566	*0.013*	56	6	0.708	*<0.001*
Vitamin B12	35	10	0.408	*0.078*	38	22	0.163	*0.311*
Folic acid	45	16	0.215	*0.255*	47	9	0.586	*0.008*
Pantothenic acid	48	16	0.472	*0.043*	41	6	0.487	*0.034*
Biotin	52	10	0.543	*0.018*	50	9	0.568	*0.011*
Vitamin C	58	13	0.595	*0.008*	50	9	0.566	*0.011*

SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids;
PUFA – Polyunsaturated fatty acids

3.5 Discussion

In the present study, nutrient intakes estimated by a SCG-FFQ were compared to those recorded in a 4-day un-weighed FD in a group of severely obese pregnant women in order to test the validity of the FFQ in this population. The results of the obese group were compared to findings obtained from lean pregnant women as controls. Despite having been extensively used in Scottish pregnant women populations, the validity and suitability of SCG-FFQ has not been tested for use in pregnancy associated with obesity.

The principal use of the FFQ is to categorize individuals according to relative nutrient intakes, i.e. to distinguish people with low intakes from those with high intakes, to avoid the necessity of assessing absolute intakes of nutrients (Sempos et al, 1992). This ability reflects the FFQ's validity and this can be evaluated by comparing it to other dietary assessment tools such as food records, or to biochemical measurements of energy or nutrients (Cade et al, 2002). A 4-day FD was chosen as the reference method due to its feasibility, detailed and quantitative estimates, and non-reliance on one's memory or ability to estimate portion sizes.

Measurement of absolute nutrient intakes between the two methods found that the FFQ generally reported higher estimates than the FD. This corresponds well with findings from other validation studies conducted in general pregnant women populations using similar dietary instruments (Brantsaeter et al, 2008, Erkkola et al, 2001, Robinson et al, 1996) or when the FFQ was compared with 24-hour food recall (Mouratidou et al, 2006b). It is suggested that this could either be due to over-reporting of food portions and frequency in the FFQ or under-reporting in the reference method used (Robinson et al, 1996). A FD kept for a few days may not cover habitual intake, may be influenced by reporting bias, and may be subject to changes in eating behaviour of participants due to the act of food recording itself (Cade et al, 2002). However, since it has been generally accepted that there is no gold standard in dietary measurement, the comparison can only be relative, and does not depict better or worse accuracy of each instrument.

The correlations observed between the FFQ and FD were comparable to other studies in our obese participants, and greater than these studies in our lean participants, (Brantsaeter et al, 2008, Mouratidou et al, 2006b, Errkola et al, 2001, Robinson et al, 1996) particularly for intakes of total energy, macronutrients and essential nutrients during pregnancy. For example, correlations coefficients for total energy intake in our obese group were r_p=0.284/r_s=0.334 whereas for lean were r_p=0.462/r_s=0.510. Others have reported correlation coefficients for total energy of r_s=0.27 (Brantsaeter et al, 2008), r_p=0.26 (Mouratidou et al, 2006b), r_p=0.24 (Errkola et al, 2001) and r_s=0.281 (Robinson et al, 1996) in general pregnant women populations. Significant agreement was also seen for important nutrients such as calcium, iron, vitamins E, B_6, B_{12} and C, and for SFA, dietary cholesterol and sugars, in both obese and lean groups in this study, consistent with others' findings (Robinson et al, 1996). However, correlation for unadjusted dietary fibre was found to be poorer in the obese group (r_p=-0.09/r_s=-0.07) as compared to our lean group (r_p=0.53/r_s=-0.40), or to findings from other studies in general pregnant women (r_p=0.36-0.47 in Mouratidou et al, 2006b, and r_p=0.48 in Errkola et al, 2001). This is likely to be due to over-reporting of portion size/frequency of dietary fibre intake in the FFQ rather than under-reporting in the FD, as it has been reported that fruits and vegetables (affecting fibre estimates) are more likely to be over-reported in FFQs (Johansson et al, 1998).

Cross-classification, the ability of the FFQ and FD to similarly classify individuals into thirds (corresponding to high, medium, or low intake), found that about half of the participants were correctly classified, and about 10 percent were grossly misclassified. Similar findings were reported by Robinson et al (1996) using cross-classification into quintiles with an average of 35% correct classification and 6% gross misclassification. Others have reported higher percentages (between 49 to 94%) of correct classification using weighed food records (Brantsaeter et al, 2008) and 24-hour diet recall (Mouratidou et al, 2006) as reference methods. These techniques have certain advantages such as better food portion estimation (from weighing) and more complete information (from multiple-pass dietary interviews) compared to the unweighed FD used in the current study.

Weighted kappa value (K_w) is another useful method for looking at ranking agreement between FFQ and the reference method. K_w value was also used to measure agreement between the two measurement methods beyond chance. This also takes partial agreement into consideration (Norman and Streiner, 2008). K_w value for total energy was lower in obese as compared to lean. K_w values were found to have poor agreement for fibre in obese, and slight agreement for copper, selenium, and vitamin B12 in lean. The highest K_w value was found for SFA in obese and calcium and zinc in lean, whereas the lowest K_w value was observed for dietary fibre in obese, and copper in lean, in agreement with the results obtained from cross-classification and correlation methods.

Having a group of lean pregnant women as controls was a particular strength of the current study, allowing an assessment of the method used, and comparison with the literature. The main limitation was that both the study and reference methods used were self-reported assessments and therefore could both be subject to similar measurement error and reporting bias. Under-reporting of food intake has been found to be particularly prevalent in obese (Poslusna et al, 2009, Ferrari et al, 2002), and pregnant (Forsum and Lof, 2007, Derbyshire et al, 2006) women populations, and occurs across dietary measurement instruments (Black et al, 2001). Since under-reporting most commonly involves recording of implausibly low total energy intake, this would affect estimates of absolute nutrient intakes. This can be addressed by adjusting for reported total energy intake, which would in essence reflect the proportion of the diet composed of each nutrient. Adjustment for energy intake reduces the possibility of measurement error, caused by misreporting of total energy intake and therefore produces nutrients intakes, which are independent of total energy (Poslusna et al, 2009). This is discussed further in Chapter 5 of this thesis.

In conclusion, the relative validity of the FFQ assessed in the current study was found to be lower in obese compared to the lean group, but the findings were comparable with those obtained in other validation studies conducted in pregnant women. This suggests a reasonable ability of the FFQ to categorize individuals according to their levels of nutrient intakes and that it is a reasonably useful tool for assessing dietary intake of obese women during pregnancy. It was also found from the assessments carried out in this study that the validity of the SCG-FFQ was better for some nutrients such as SFA, dietary cholesterol, sugars, and vitamin C, but poorer for dietary fibre, when assessed in severely obese pregnant women. Overall, it was felt that the SCG-FFQ was a suitable tool to evaluate food intake in the whole study group.

CHAPTER 4

Assessment of dietary intake and its associated factors

Chapter 4

4.1 Introduction

Pregnancy is a critical period during which maternal nutrition is of vital importance for the health of both mother and baby. Extra dietary energy is required during pregnancy partly to compensate for the energy deposition in maternal and fetal tissues and the increase in basal metabolic rate (Butte et al, 2004). These increased requirements for energy and a variety of other nutrients can be met by following a healthy and balanced diet.

However, with one quarter of adult women classified as obese in the UK (WHO Media Centre, 2011), the most prominent nutritional problems faced by pregnant women in western societies are overnutrition, pre-pregnancy overweight and obesity, and excessive weight gain during pregnancy. Maternal obesity has been associated with various undesirable complications to both mother and baby, in both the short and long-term, as discussed in detail in Chapter 1 of this thesis. It is therefore essential that obese pregnant women in particular are encouraged to eat healthily to ensure the optimal health outcomes during and after pregnancy. However, data about food intake of obese women during pregnancy are scarce and more information is needed before appropriate interventions can be planned.

In this chapter, the dietary intake of obese and lean women was assessed by using the Scottish Collaborative Group Food Frequency Questionnaire (SCG-FFQ), having validated this questionnaire against a food diary (FD) in a subsample of the study population as discussed in Chapter 3 of this thesis. The reported total energy and nutrients intakes were compared against recommended nutrient intakes (RNI). Other factors which may influenced dietary intake such as appetite, general nutrition knowledge and eating behaviours were also assessed to provide further insights about food intake-related behaviour of severely obese women during pregnancy.

4.2 Hypothesis and aims

The hypothesis of this chapter was that severely obese women consume more total calories and other nutrients than lean women throughout pregnancy.

The aims of this chapter were to assess in a cohort of severely obese and lean pregnant women:

a) food intake (total energy, macro- and micronutrients) using SCG-FFQ

b) whether RNIs for important nutrients during pregnancy are met

c) appetite, general nutrition knowledge, and eating behaviours, using validated questionnaires

4.3 Methods

4.3.1 Study design

This is a case-control study comparing obese and lean pregnant women who were recruited among participants from a larger prospective cohort study (for details refer Section 2.4.4).

4.3.2 Ethical approval

The study was approved by the Lothian NHS Research Ethics Committee and all subjects gave written informed consent.

4.3.3 Subject recruitment

The Energy Balance in Pregnancy study participants were asked to fill in the SCG-FFQ and the Council on Nutrition Appetite Questionnaire (CNAQ) twice during pregnancy; early (during the first visit to the clinic, between 12-20 gestational weeks), and late pregnancy (during second or third visit to the clinic, between 27-32 gestational weeks). They were also asked to complete the General Nutrition Knowledge Questionnaire (GNKQ) as well as the Dutch Eating Behaviour Questionnaire (DEBQ).

4.3.4 Collection of dietary intake data

Food intake was measured by using a validated, semi-quantitative SCG-FFQ version 6.6 (Scottish Collaborative Group, University of Aberdeen, UK). In this questionnaire, subjects describe the amounts and frequency of each of the 170 foods and drinks on the list that they have eaten over the last 2 to 3 months (details were presented in Section 2.5.1).

A subgroup of the women was asked to complete a validated semi-quantitative GNKQ (Parmentle and Wardle, 1999). This questionnaire consists of 4 independent sections: dietary recommendations, food sources, food choices, and diet disease relationship (details are presented in Section 2.5.3).

A subgroup of the women was asked to complete a validated CNAQ (Wilson et al, 2005). This appetite assessment tool contains 7 questions about general perception about current appetite, hunger, food taste, number of meals eaten per day, and feeling of nausea when eating (details are presented in Section 2.5.4).

A subgroup of the women was asked to complete a validated DEBQ (van Strien et al, 1986). This questionnaire provides Likert Scale responses and consists of 3 independent sections on eating behaviour and these include restraint, emotional, and externally-cued eating (details are presented in Section 2.5.5)

4.3.5 Data analysis

Data from completed questionnaires were entered into a Microsoft Access entry package provided by the questionnaire administrator (Scottish Collaborative Group, University of Aberdeen) and were exported to the administrator to be analyzed (as detailed in Section

2.7.1). The results included total energy intake (in both kilocalories and kilojoules) and 38 other nutrients, as listed in Table 2.1. Intakes of nutrients were compared with the RNI suggested for pregnant women (age 19 to 50 years) by Food and Nutrition Board (Institute of Medicine, 1997-2010).

The GNKQ was analyzed manually (as detailed in Section 2.7.3) following the answer scheme as provided by the questionnaire developer (Parmenter and Wardle, 1999).

The CNAQ was analyzed manually (as detailed in Section 2.7.4) following the instructions provided in a publication that discussed the use of this questionnaire (Wilson et al, 2005).

The DEBQ was analyzed manually (as detailed in Section 2.7.5) based on instructions published by the questionnaire developers (van Strien et al, 1986).

4.3.6 Statistical methods

Normal distribution of data was assessed visually using histograms and Q-Q plots, and by using Kolmogorov-Smirnov test. Total energy and nutrient intakes were not normally distributed and were normalized by using log-transformation. The distribution of data obtained from appetite and nutrition knowledge assessment were normal.

Nutrient intakes were adjusted for total energy intake using the residual method calculated from regression of nutrient intake as the dependent variable and total energy as the independent variable (Willet and Stampfer, 1986). Nutrient intakes from dietary supplements were not included in any of the analyses. Comparisons between obese and lean groups, and between early and late pregnancy were analysed using independent t-test. Comparisons between early and late pregnancy in subjects with paired data available in each group were analysed using paired t-test.

Except for paired data, all other results were adjusted for age, parity, ethnicity, Deprivation Category (DEPCAT) status, total activity (MET-hours/day), working status and gestation period, using linear regression analysis.

The significance level was set at 5% and all statistical analyses were performed using SPSS version 14.0 (SPSS Inc., Chicago, IL, USA). Data are presented as median (25^{th} and 75^{th} percentile) or mean (standard error mean) unless stated otherwise.

4.4 Results

4.4.1 Total energy and nutrient intakes

In the obese group, a total of 13 questionnaires (9 from early and 4 from late pregnancy) were not analyzed due to incompletion or not being returned. Data were available from 139 obese women who filled in the SCG-FFQ in early pregnancy and 137 in late pregnancy. In the lean group, 4 questionnaires (3 in early, 1 in late pregnancy) were either not returned or not fully completed and thus were not analyzed. The SCG-FFQ was completed by 80 and 68 lean women during early and late pregnancy, respectively. The demographic characteristics of all the subjects who completed the SCG-FFQ are presented in Table 4.1. The obese group was significantly younger, had higher parity, and lower DEPCAT status than lean. Ethnicity was not significantly different between groups. The age and parity characteristics were slightly different compared with the subsample of women who participated in the validation study (Chapter 3) where obese women in the validation study population were of similar age and parity to lean (Table 3.1). Overall, the demographic characteristics such as age, BMI at booking, parity, and ethnicity, were not significantly different between the study participants who did or did not take part in this dietary assessment study (refer Appendix E). However, a higher percentage of the participants who did not fill in the SCG-FFQ were of low and high DEPCAT status compared to those who did (*P=0.021*).

Table 4.1

Demographic characteristics of subjects who completed Scottish Collaborative Group Food Frequency Questionnaire

		Obese (n=162)		Lean (n=85)		
		Mean	(Range or %)	Mean	(Range or %)	*P Value*
Age (years)		31.6	(20.3 – 44.5)	33.5	(21.1 – 42.3)	*P=0.006*‡
BMI at booking (kg/m^2)		44.0	(37.9 – 61.1)	22.6	(19.4 – 27.6)	*P<0.001*‡
Parity	Nulliparous	76	(47.5%)	53	(63.1%)	*P=0.039*†
	Multiparous	84	(52.5%)	31	(36.9%)	
Ethnicity	Caucasian	156	(95.7%)	84	(100%)	*P=0.099*†
	Non-Caucasian	7	(4.3%)			
DEPCAT status	Low (1 to 2)	23	(14.1%)	1	(1.2%)	*P<0.001*†
	Middle (3 to 5)	126	(77.3%)	58	(69.0%)	
	High (6 to 7)	14	(8.6%)	25	(29.8%)	

‡ Tested using independent t-test; † Tested using chi square test; DEPCAT – Deprivation Category

Overall, the obese group reported to have significantly reduced their total calorie intake from early to late pregnancy (Figure 4.1). Intake of most nutrients also decreased between early and late pregnancy, but only intake of sugars remained significant after adjustment for total energy intake and demographic data (Table 4.2a). Self-reported intake of total calories and other nutrients were similar between early and late pregnancy in the lean group (Table 4.2b). Changes in nutrient intakes throughout pregnancy were also assessed in women with data for both early and late pregnancy (paired data) and were found to have similar patterns to data from the complete study population, in both obese and lean (Tables 4.2c and 4.2d).

Figure 4.1

Comparison of reported total energy intake (kcal/day) within and between obese and lean groups, during early and late pregnancy.

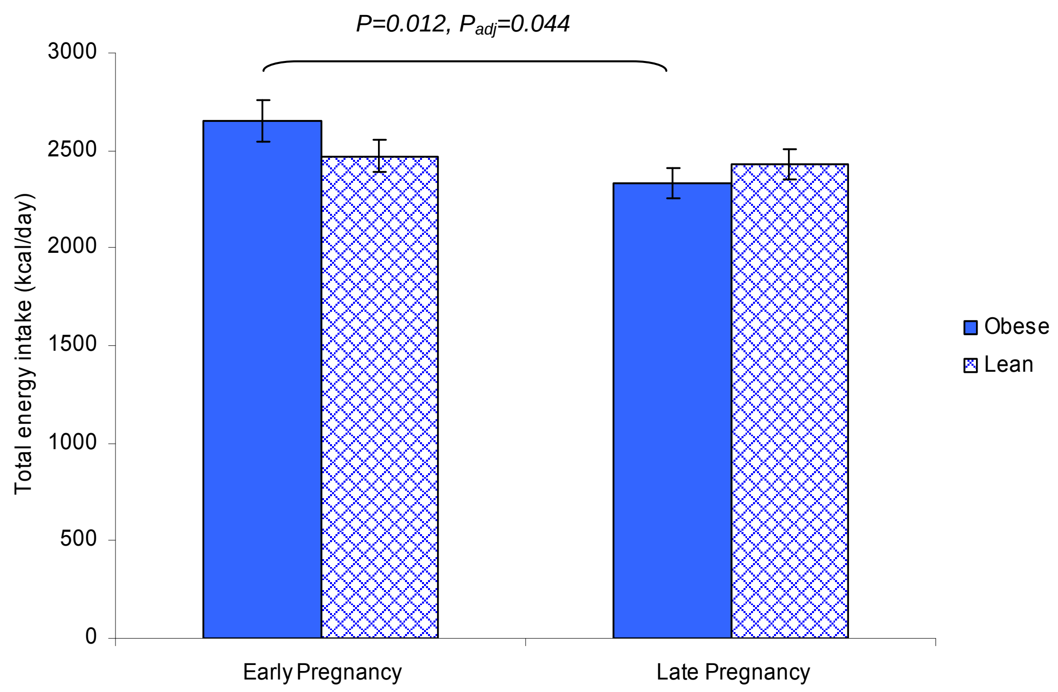


Table 4.2a

Median (interquartile range) of daily nutrient intakes (obese group)

Nutrient	Early Pregnancy (n=139)		Late Pregnancy (n=137)		*P value* [1]	*P value* [2]	*P value* [3]	*P value* [4]
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})				
Energy (kcal)	2444	(2002, 3044)	2173	(1747, 2675)	*0.012*	-	*0.044*	-
Protein (g)	98.7	(74.2, 124.5)	87.7	(69.1, 111.6)	*0.040*	*0.540*	*0.116*	*0.654*
Fat (g)	95.8	(74.7, 121.9)	87.1	(65.0, 106.4)	*0.019*	*0.795*	*0.090*	*0.460*
Carbohydrate (g)	310	(249, 385)	279	(227, 347)	*0.015*	*0.842*	*0.029*	*0.285*
SFA (g)	38.5	(28.8, 50.6)	34.8	(24.7, 43.4)	*0.031*	*0.546*	*0.090*	*0.602*
MUFA (g)	33.5	(25.4, 42.9)	29.8	(21.6, 36.6)	*0.021*	*0.823*	*0.088*	*0.619*
PUFA (g)	16.3	(11.8, 22.0)	13.9	(11.0, 18.4)	*0.020*	*0.812*	*0.165*	*0.354*
Cholesterol (mg)	291	(206, 386)	269	(197, 374)	*0.262*	*0.234*	*0.293*	*0.515*
Sugars (g)	150	(113, 194)	133	(99, 174)	*0.023*	*0.692*	*0.003*	*0.015*
Starch (g)	155	(122, 192)	136	(107, 175)	*0.033*	*0.811*	*0.356*	*0.064*
Fibre (g)	20.5	(16.4, 26.2)	19.0	(13.9, 24.3)	*0.030*	*0.818*	*0.107*	*0.988*
Sodium (mg)	3393	(2476, 4002)	2926	(2298, 3526)	*0.012*	*0.627*	*0.091*	*0.716*
Potassium (mg)	3966	(3068, 5083)	3462	(2845, 4648)	*0.021*	*0.878*	*0.036*	*0.402*
Calcium (mg)	1197	(946, 1588)	1071	(850, 1389)	*0.007*	*0.360*	*0.044*	*0.516*
Magnesium (mg)	402	(330, 496)	359	(289, 452)	*0.007*	*0.299*	*0.107*	*0.539*
Phosphorus (mg)	1788	(1431, 2330)	1652	(1274, 2097)	*0.008*	*0.374*	*0.068*	*0.906*
Iron (mg)	14.50	(11.62, 18.88)	12.99	(10.13, 16.54	*0.015*	*0.642*	*0.184*	*0.352*
Copper (mg)	2.91	(2.16, 4.22)	2.66	(2.04, 3.43)	*0.054*	*0.933*	*0.417*	*0.358*
Zinc (mg)	12.2	(9.25, 15.05)	10.9	(8.4, 13.8)	*0.040*	*0.583*	*0.089*	*0.956*
Chloride (mg)	5000	(3828, 6238)	4428	(3552, 5432)	*0.012*	*0.645*	*0.092*	*0.666*
Manganese (mg)	3.7	(2.9, 4.7)	3.2	(2.6, 4.3)	*0.060*	*0.934*	*0.432*	*0.240*
Selenium (µg)	64.0	(46, 83)	57.5	(41, 77)	*0.070*	*0.809*	*0.385*	*0.256*
Iodine (µg)	246	(169, 312)	222	(157, 291)	*0.057*	*0.900*	*0.054*	*0.489*
Retinol (µg)	320	(224, 465)	288	(196, 428)	*0.023*	*0.697*	*0.427*	*0.281*
B-carotene (µg)	4175	(2338, 6246)	3261	(2227, 5105)	*0.051*	*0.530*	*0.358*	*0.784*
Vitamin D (µg)	3.15	(2.03, 4.58)	2.78	(2.02, 4.37)	*0.208*	*0.610*	*0.739*	*0.216*
Vitamin E (mg)	11.53	(8.48, 15.42)	10.02	(7.11, 13.04)	*0.017*	*0.626*	*0.094*	*0.887*
Thiamine (mg)	2.04	(1.56, 2.51)	1.76	(1.47, 2.19)	*0.027*	*0.992*	*0.149*	*0.543*
Riboflavin (mg)	2.17	(1.54, 2.84)	1.88	(1.41, 2.58)	*0.014*	*0.428*	*0.046*	*0.406*
Niacin (mg)	24.5	(18.4, 31.3)	22.4	(16.3, 28.6)	*0.048*	*0.907*	*0.200*	*0.555*
Potential niacin (mg)	20.5	(16.4, 26.7)	18.3	(14.2, 24.0)	*0.063*	*0.327*	*0.175*	*0.348*
Vitamin B6 (mg)	2.70	(2.06, 3.28)	2.46	(1.84, 3.10)	*0.047*	*0.726*	*0.152*	*0.616*
Vitamin B12 (µg)	6.2	(4.35, 8.60)	5.7	(4.0, 7.7)	*0.075*	*0.939*	*0.997*	*0.906*
Folic acid (µg)	312	(226, 396)	274	(202, 362)	*0.018*	*0.526*	*0.162*	*0.804*
Pantothenic acid (mg)	6.47	(4.78, 8.14)	5.68	(4.48, 7.68)	*0.034*	*0.717*	*0.050*	*0.564*
Biotin (µg)	41.8	(31.6, 52.0)	37.1	(26.9, 48.6)	*0.054*	*0.783*	*0.101*	*0.908*
Vitamin C (mg)	167	(112, 230)	147	(85.8, 197.5)	*0.016*	*0.263*	*0.053*	*0.346*
Vitamin K (mg)	35.5	(22.6, 69.5)	33.5	(17.4, 66.5)	*0.154*	*0.857*	*0.512*	*0.705*
Alcohol (g)	0.0	(0.0, 0.0)	0.0	(0.0, 0.0)	*0.216*	*0.555*	*0.147*	*0.349*

P_{25} – 25th percentile, P_{75} – 75th percentile;
SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids; PUFA – Polyunsaturated fatty acids
P value [1] – log-transformed, crude intakes (independent t-test)
P value [2] – log-transformed, energy-adjusted intakes (independent t-test)
P value [3] – log-transformed, crude intakes, adjusted for age, parity, ethnicity, DEPCAT, total activity (MET-hours/day), working status and gestation period (linear regression)
P value [4] – log-transformed, energy-adjusted intakes, adjusted for age, parity, ethnicity, DEPCAT, total activity (MET-hours/day), working status and gestation period (linear regression)

Table 4.2b

Median (interquartile range) of daily nutrient intakes (lean group)

Nutrient	Early Pregnancy (n=80)		Late Pregnancy (n=68)		*P value* [1]	*P value* [2]	*P value* [3]	*P value* [4]
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})				
Energy (kcal)	2312	(1944, 2823)	2354	(1962, 2764)	*0.851*	-	*0.710*	-
Protein (g)	93.4	(74.0, 113.9)	90.1	(74.9, 117.0)	*0.901*	*0.937*	*0.830*	*0.810*
Fat (g)	90.3	(73.0, 115.2)	91.8	(72.6, 121.7)	*0.581*	*0.282*	*0.852*	*0.148*
Carbohydrate (g)	302	(251, 354)	294	(261, 352)	*0.992*	*0.650*	*0.312*	*0.112*
SFA (g)	34.3	(27.7, 46.4)	36.4	(28.3, 49.2)	*0.391*	*0.133*	*0.707*	*0.146*
MUFA (g)	30.0	(25.2, 40.6)	31.9	(24.5, 40.4)	*0.643*	*0.446*	*0.790*	*0.125*
PUFA (g)	15.8	(12.7, 19.8)	15.0	(12.8, 20.2)	*0.926*	*0.884*	*0.982*	*0.485*
Cholesterol (mg)	277	(188, 342)	255	(180, 365)	*0.849*	*0.904*	*0.738*	*0.869*
Sugars (g)	126	(108, 176)	135	(111, 178)	*0.577*	*0.558*	*0.465*	*0.527*
Starch (g)	151	(132, 198)	159	(121, 182)	*0.588*	*0.256*	*0.288*	*0.200*
Fibre (g)	22.7	(19.8, 29.1)	23.3	(19.1, 27.4)	*0.603*	*0.326*	*0.864*	*0.825*
Sodium (mg)	3200	(2575, 3937)	3239	(2646, 3897)	*0.865*	*0.979*	*0.619*	*0.082*
Potassium (mg)	3876	(3152, 4645)	3801	(3306, 4765)	*0.961*	*0.661*	*0.640*	*0.829*
Calcium (mg)	1231	(1004, 1496)	1268	(1015, 1621)	*0.579*	*0.446*	*0.670*	*0.797*
Magnesium (mg)	426	(374, 518)	430	(360, 527)	*0.840*	*0.434*	*0.558*	*0.620*
Phosphorus (mg)	1754	(1478, 2086)	1753	(1529, 2215)	*0.750*	*0.713*	*0.699*	*0.909*
Iron (mg)	16.53	(13.77, 19.51)	16.31	(13.63, 19.87)	*0.914*	*0.656*	*0.292*	*0.208*
Copper (mg)	3.21	(2.48, 4.04)	3.24	(2.65, 4.09)	*0.765*	*0.811*	*0.089*	*0.899*
Zinc (mg)	12.0	(9.6, 14.3)	11.8	(9.8, 15.1)	*0.896*	*0.950*	*0.609*	*0.689*
Chloride (mg)	4828	(3899, 6017)	4817	(4103,5885)	*0.869*	*0.992*	*0.606*	*0.071*
Manganese (mg)	4.6	(4.0, 5.8)	4.5	(3.5, 5.7)	*0.383*	*0.180*	*0.150*	*0.096*
Selenium (μg)	64	(49.5, 77.5)	62	(51, 78)	*0.831*	*0.576*	*0.520*	*0.625*
Iodine (μg)	229	(181, 307)	249	(187, 331)	*0.612*	*0.595*	*0.505*	*0.563*
Retinol (μg)	319	(220, 436)	312	(220, 504)	*0.555*	*0.453*	*0.929*	*0.820*
B-carotene (μg)	4362	(3053, 6641)	4219	(2661, 6714)	*0.895*	*0.811*	*0.372*	*0.223*
Vitamin D (μg)	3.80	(2.62, 5.58)	4.01	(2.56, 5.80)	*0.988*	*0.922*	*0.910*	*0.693*
Vitamin E (mg)	12.0	(9.73, 14.95)	12.32	(9.03, 15.41)	*0.819*	*0.541*	*0.565*	*0.724*
Thiamine (mg)	1.99	(1.64, 2.32)	1.98	(1.62, 2.39)	*0.921*	*0.645*	*0.403*	*0.366*
Riboflavin (mg)	2.13	(1.84, 2.65)	2.23	(1.78, 2.86)	*0.479*	*0.404*	*0.268*	*0.216*
Niacin (mg)	23.0	(18.7, 27.3)	22.2	(18.0, 28.2)	*0.900*	*0.715*	*0.550*	*0.675*
Potential niacin (mg)	20.3	(15.5, 24.2)	19.3	(16.1, 25.9)	*0.797*	*0.826*	*0.780*	*0.968*
Vitamin B6 (mg)	2.50	(2.04, 3.07)	2.47	(2.05, 3.24)	*0.893*	*0.967*	*0.197*	*0.463*
Vitamin B12 (μg)	5.9	(4.5, 8.5)	6.0	(4.9, 8.6)	*0.818*	*0.874*	*0.997*	*0.771*
Folic acid (μg)	355	(284, 428)	362	(288, 432)	*0.917*	*0.746*	*0.383*	*0.423*
Pantothenic acid (mg)	6.08	(4.88, 7.66)	6.14	(5.13, 7.86)	*0.685*	*0.640*	*0.490*	*0.478*
Biotin (μg)	45.1	(36.4, 54.8)	44.6	(38.2, 59.3)	*0.735*	*0.761*	*0.215*	*0.097*
Vitamin C (mg)	154	(118, 204)	151	(111, 202)	*0.473*	*0.349*	*0.489*	*0.602*
Vitamin K (mg)	69.9	(43.4, 137.2)	62.6	(40.6, 144.5)	*0.912*	*0.847*	*0.706*	*0.571*
Alcohol (g)	0.0	(0.0, 2.4)	0.0	(0.0, 2.4)	*0.878*	*0.854*	*0.770*	*0.721*

P_{25} – 25^{th} percentile, P_{75} – 75^{th} percentile;
SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids; PUFA – Polyunsaturated fatty acids
P value [1] – log-transformed, crude intakes (independent t-test)
P value [2] – log-transformed, energy-adjusted intakes (independent t-test)
P value [3] – log-transformed, crude intakes, adjusted for age, parity, ethnicity, DEPCAT, total activity (MET-hours/day), working status and gestation period (linear regression)
P value [4] – log-transformed, energy-adjusted intakes, adjusted for age, parity, ethnicity, DEPCAT, total activity (MET-hours/day), working status and gestation period (linear regression)

Table 4.2c

Median (interquartile range) of daily nutrient intakes for paired data (obese group, n=114)

Nutrient	Early Pregnancy		Late Pregnancy		*P value* [1]	*P value* [2]
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})		
Energy (kcal)	2444	(2008, 3047)	2166	(1760, 2715)	*<0.001*	-
Protein (g)	99.1	(72.6, 125.7)	88.9	(69.1, 111.3)	*0.003*	*0.704*
Fat (g)	95.7	(73.7, 120.5)	88.0	(66.1, 108.7)	*0.001*	*0.689*
Carbohydrate (g)	321	(258, 387)	282.9	(229, 348)	*<0.001*	*0.538*
SFA (g)	37.9	(28.5, 50.2)	35.2	(24.9, 44.2)	*0.003*	*0.871*
MUFA (g)	33.5	(25.0, 41.2)	30.0	(22.1, 37.0)	*0.001*	*0.576*
PUFA (g)	16.0	(11.9, 21.5)	14.1	(11.1, 18.6)	*0.001*	*0.912*
Cholesterol (mg)	296	(199, 393)	273	(189, 375)	*0.047*	*0.392*
Sugars (g)	153	(114, 195)	13.34	(104, 174)	*<0.001*	*0.354*
Starch (g)	155	(124, 193)	138	(109, 179)	*0.008*	*0.845*
Fibre (g)	22.0	(16.5 26.4)	19.3	(14.8, 23.8)	*<0.001*	*0.751*
Sodium (mg)	3339	(2395, 4084)	2933	(2302, 3632)	*0.002*	*0.787*
Potassium (mg)	4045	(3027, 5220)	3467	(2861, 4599)	*<0.001*	*0.661*
Calcium (mg)	1200	(944, 1596)	1065	(887, 1381)	*0.001*	*0.585*
Magnesium (mg)	406	(332, 492)	360	(293, 449)	*<0.001*	*0.767*
Phosphorus (mg)	1803	(1447, 2333)	1651	(,1276)2143	*<0.001*	*0.725*
Iron (mg)	14.52	(11.43, 18.77)	13.31	(10.14, 17.33)	*0.002*	*0.668*
Copper (mg)	2.91	(2.20, 4.21)	2.75	(2.05, 3.50)	*0.021*	*0.819*
Zinc (mg)	12.2	(9.4, 15.1)	11.1	(8.4, 13.8)	*0.003*	*0.794*
Chloride (mg)	4990	(3724, 6274)	4433	(3572, 5548)	*0.002*	*0.888*
Manganese (mg)	3.7	(2.9, 4.7)	3.2	(2.6, 4.3)	*0.003*	*0.702*
Selenium (µg)	64	(47, 84)	57	(42, 74)	*0.008*	*0.805*
Iodine (µg)	246	(166, 318)	164	(220, 292)	*0.017*	*0.916*
Retinol (µg)	311	(221, 467)	291	(195, 428)	*0.003*	*0.986*
B-carotene (µg)	4175	(2299, 6288)	3156	(2222, 5001)	*<0.001*	*0.622*
Vitamin D (µg)	3.10	(2.08, 4.61)	2.85	(2.05, 4.26)	*0.126*	*0.472*
Vitamin E (mg)	11.73	(8.33, 14.9)	10.06	(7.11, 12.82)	*<0.001*	*0.902*
Thiamine (mg)	2.09	(1.55, 2.59)	1.79	(1.49, 2.22)	*0.001*	*0.758*
Riboflavin (mg)	2.16	(1.58, 2.94)	1.89	(1.44, 2.58)	*0.001*	*0.439*
Niacin (mg)	24.5	(18.3, 31.4)	22.5	(16.9, 27.5)	*0.005*	*0.890*
Potential niacin (mg)	20.6	(16.3, 27.0)	18.4	(,14.3)23.9	*0.007*	*0.765*
Vitamin B6 (mg)	2.76	(2.06, 3.31)	2.49	(1.85, 3.07)	*0.003*	*0.904*
Vitamin B12 (µg)	6.2	(4.3, 8.7)	5.7	(4.1, 7.7)	*0.009*	*0.861*
Folic acid (µg)	312	(224, 401)	276	(203, 349)	*0.001*	*0.477*
Pantothenic acid (mg)	6.59	(4.65, 8.16)	5.66	(4.58, 7.23)	*<0.001*	*0.699*
Biotin (µg)	42.9	(31.4, 51.5)	37.1	(27.0, 47.8)	*0.005*	*0.948*
Vitamin C (mg)	163	(115, 229)	147	(85, 197)	*<0.001*	*0.777*
Vitamin K (mg)	35.5	(23.0, 69.3)	34.3	(17.5, 65.8)	*0.013*	*0.737*
Alcohol (g)	0.0	(0.0, 0.0)	0.0	(0.0, 0.0)	*0.179*	*0.744*

P_{25} – 25^{th} percentile, P_{75} – 75^{th} percentile;
SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids; PUFA – Polyunsaturated fatty acids
P value [1] – log-transformed, crude intakes (paired t-test)
P value [2] – log-transformed, energy-adjusted (paired t-test)

Table 4.2d

Median (interquartile range) of daily nutrient intakes for paired data (lean group, n=62)

Nutrient	Early Pregnancy		Late Pregnancy		*P value* [1]	*P value* [2]
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})		
Energy (kcal)	2312	(1865, 2823)	2354	(1983, 2762)	*0.184*	-
Protein (g)	93.4	(73.8, 114.8)	90.5	(77.0, 117.2)	*0.396*	*0.496*
Fat (g)	90.3	(71.9, 115.2)	91.8	(72.4, 121.5)	*0.181*	*0.457*
Carbohydrate (g)	293	(247, 354)	294	(263, 354)	*0.126*	*0.298*
SFA (g)	34.3	(27.0, 46.4)	36.2	(28.2, 47.7)	*0.081*	*0.698*
MUFA (g)	30.0	(25.1, 40.5)	31.9	(24.4, 40.3)	*0.275*	*0.300*
PUFA (g)	15.8	(12.4, 19.8)	15.2	(12.8, 20.8)	*0.388*	*0.913*
Cholesterol (mg)	270	(188, 353)	257	(176, 362)	*0.973*	*0.151*
Sugars (g)	124	(104, 178)	134	(111, 175)	*0.030*	*0.056*
Starch (g)	151	(122, 198)	162	(124, 186)	*0.426*	*0.620*
Fibre (g)	22.7	(19.7, 29.1)	23.5	(19.8, 27.4)	*0.524*	*0.604*
Sodium (mg)	3200	(2485, 3969)	3257	(2721, 3896)	*0.309*	*0.705*
Potassium (mg)	3821	(3058, 4594)	3813	(3336, 4730)	*0.302*	*0.338*
Calcium (mg)	1259	(1004, 1502)	1269	(1015, 1627)	*0.154*	*0.193*
Magnesium (mg)	422	(364, 521)	430	(376, 529)	*0.494*	*0.478*
Phosphorus (mg)	1725	(1482, 2096)	1765	(1538, 2222)	*0.236*	*0.352*
Iron (mg)	16.78	(13.77, 19.14)	16.38	(13.99, 20.34)	*0.415*	*0.453*
Copper (mg)	3.14	(2.40, 4.11)	3.31	(2.66, 4.11)	*0.319*	*0.690*
Zinc (mg)	12.0	(9.7, 14.6)	11.9	(9.9, 15.2)	*0.381*	*0.665*
Chloride (mg)	4845	(3751, 6096)	4871	(4164, 5872)	*0.241*	*0.828*
Manganese (mg)	4.4	(3.8, 5.8)	4.6	(3.8, 5.7)	*0.897*	*0.657*
Selenium (µg)	64	(50, 76)	62	(52, 80)	*0.554*	*0.579*
Iodine (µg)	227	(180, 306)	250	(188, 332)	*0.149*	*0.656*
Retinol (µg)	319	(214, 443)	312	(210, 492)	*0.275*	*0.688*
B-carotene (µg)	4362	(3053, 7163)	4300	(2840, 6726)	*0.673*	*0.306*
Vitamin D (µg)	3.80	(2.69, 5.42)	4.01	(2.61, 5.95)	*0.855*	*0.221*
Vitamin E (mg)	11.69	(9.54, 14.95)	12.49	(9.62, 15.72)	*0.525*	*0.775*
Thiamine (mg)	1.95	(1.59, 2.32)	1.98	(1.63, 2.41)	*0.294*	*0.695*
Riboflavin (mg)	2.13	(1.83, 2.67)	2.25	(1.82, 2.86)	*0.114*	*0.137*
Niacin (mg)	22.9	(18.4, 26.8)	22.4	(18.6, 28.4)	*0.393*	*0.785*
Potential niacin (mg)	20.1	(15.4, 24.4)	19.6	(16.2, 25.9)	*0.275*	*0.593*
Vitamin B6 (mg)	2.50	(1.96, 3.02)	2.47	(2.05, 3.24)	*0.306*	*0.840*
Vitamin B12 (µg)	6.2	(4.5, 8.1)	6.0	(4.9, 8.5)	*0.679*	*0.865*
Folic acid (µg)	357	(282, 426)	373	(298, 437)	*0.434*	*0.252*
Pantothenic acid (mg)	6.05	(4.73, 7.71)	6.14	(5.16, 7.87)	*0.153*	*0.436*
Biotin (µg)	44.6	(36.1, 54.8)	44.7	(39.1, 59.6)	*0.155*	*0.870*
Vitamin C (mg)	146	(114, 200)	151	(110, 203)	*0.642*	*0.580*
Vitamin K (mg)	75.7	(44.6, 137.2)	63.5	(44.9, 164.1)	*0.959*	*0.770*
Alcohol (g)	0.0	(0.0, 2.4)	0.0	(0.0, 2.4)	*0.837*	*0.553*

P_{25} – 25th percentile, P_{75} – 75th percentile;
SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids; PUFA – Polyunsaturated fatty acids
P value [1] – log-transformed, crude intakes (paired t-test)
P value [2] – log-transformed, energy-adjusted (paired t-test)

Self-reported total energy and macronutrient (protein, carbohydrate and fat) intakes were not significantly different between obese and lean groups, both during early and late pregnancy (Tables 4.2e and 4.2f). However, essential micronutrients such as calcium, iron, vitamin D and folic acid were found to be significantly lower in obese groups' diets as compared to lean throughout pregnancy. The obese group also reported significantly lower intake of fibre than lean throughout pregnancy, and higher intake of saturated fatty acids (SFA) in early pregnancy. Intakes of magnesium, manganese, biotin, vitamin K, and alcohol were also significantly lower in obese than lean throughout pregnancy.

Even though total calorie intake was similar in both groups, adequacy of nutrient intake was poorer in obese as compared to lean, throughout pregnancy (Tables 4.2g). The number of obese participants who did not meet nutrient RNIs also increased from early to late pregnancy. Less than a quarter (range 18 to 23%) of the study population in the obese group met the RNIs set for fibre, vitamin D, vitamin E and vitamin K. Only 30% in early pregnancy and 24% in late pregnancy met the recommended value for potassium. Intakes of these nutrients were slightly higher in lean (ranging from 25 to 39%). 95% or more of obese group met the RNIs for sodium, phosphorus, copper and chloride throughout pregnancy. 95% of the lean group met the RNIs for the same nutrients, and also for manganese, vitamin B12 and vitamin C. Both groups however reported low intakes of iron and folic acid which are important during pregnancy, with only 2 to 5% meeting the RNIs.

Table 4.2e

Median (interquartile range) of daily nutrient intakes (early pregnancy)

Nutrient	Obese (n=139)		Lean (n=80)		*P value*[1]	*P value*[2]	*P value*[3]	*P value*[4]
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})				
Energy (kcal)	2444	(2002, 3044)	2312	(1944, 2823)	*0.442*	*-*	*0.181*	*-.*
Protein (g)	98.7	(74.2, 124.5)	93.4	(74.0, 113.9)	*0.638*	*0.577*	*0.174*	*0.653*
Fat (g)	95.8	(74.7, 121.9)	90.3	(73.0, 115.2)	*0.447*	*0.924*	*0.402*	*0.217*
Carbohydrate (g)	310	(249, 385)	302	(251, 354)	*0.418*	*0.783*	*0.093*	*0.228*
SFA (g)	38.5	(28.8, 50.6)	34.3	(27.7, 46.4)	*0.181*	*0.114*	*0.789*	*0.025*
MUFA (g)	33.5	(25.4, 42.9)	30.0	(25.2, 40.6)	*0.506*	*0.889*	*0.369*	*0.386*
PUFA (g)	16.3	(11.8, 22.0)	15.8	(12.7, 19.8)	*0.790*	*0.402*	*0.208*	*0.879*
Cholesterol (mg)	291	(206, 386)	277	(188, 342)	*0.166*	*0.249*	*0.724*	*0.394*
Sugars (g)	150	(113, 194)	126	(108, 176)	*0.103*	*0.078*	*0.193*	*0.777*
Starch (g)	155	(122, 192)	151	(132, 198)	*0.722*	*0.029*	*0.082*	*0.222*
Fibre (g)	20.5	(16.4, 26.2)	22.7	(19.8, 29.1)	*0.049*	*<0.001*	*0.007*	*0.010*
Sodium (mg)	3393	(2476, 4002)	3200	(2575, 3937)	*0.677*	*0.490*	*0.535*	*0.165*
Potassium (mg)	3966	(3068, 5083)	3876	(3152, 4645)	*0.730*	*0.404*	*0.078*	*0.246*
Calcium (mg)	1197	(946, 1588)	1231	(1004, 1496)	*0.510*	*0.011*	*0.023*	*0.018*
Magnesium (mg)	402	(330, 496)	426	(374, 518)	*0.173*	*<0.001*	*0.011*	*0.001*
Phosphorus (mg)	1788	(1431, 2330)	1754	(1478, 2086)	*0.858*	*0.131*	*0.098*	*0.240*
Iron (mg)	14.50	(11.62, 18.88)	16.53	(13.77, 19.51)	*0.040*	*<0.001*	*0.003*	*0.000*
Copper (mg)	2.91	(2.16, 4.22)	3.21	(2.48, 4.04)	*0.668*	*0.009*	*0.035*	*0.026*
Zinc (mg)	12.2	(9.25, 15.05)	12.0	(9.6, 14.3)	*0.414*	*0.064*	*0.098*	*0.294*
Chloride (mg)	5000	(3828, 6238)	4828	(3899, 6017)	*0.737*	*0.381*	*0.517*	*0.183*
Manganese (mg)	3.7	(2.9, 4.7)	4.6	(4.0, 5.8)	*<0.001*	*<0.001*	*<0.001*	*<0.001*
Selenium (µg)	64.0	(46, 83)	64	(49.5, 77.5)	*0.713*	*0.115*	*0.133*	*0.423*
Iodine (µg)	246	(169, 312)	229	(181, 307)	*0.866*	*0.256*	*0.040*	*0.084*
Retinol (µg)	320	(224, 465)	319	(220, 436)	*0.328*	*0.554*	*0.088*	*0.529*
B-carotene (µg)	4175	(2338, 6246)	4362	(3053, 6641)	*0.166*	*0.036*	*0.061*	*0.173*
Vitamin D (µg)	3.15	(2.03, 4.58)	3.80	(2.62, 5.58)	*0.051*	*0.002*	*0.044*	*0.024*
Vitamin E (mg)	11.53	(8.48, 15.42)	12.0	(9.73, 14.95)	*0.300*	*0.001*	*0.054*	*0.138*
Thiamine (mg)	2.04	(1.56, 2.51)	1.99	(1.64, 2.32)	*0.956*	*0.130*	*0.087*	*0.244*
Riboflavin (mg)	2.17	(1.54, 2.84)	2.13	(1.84, 2.65)	*0.699*	*0.114*	*0.012*	*0.014*
Niacin (mg)	24.5	(18.4, 31.3)	23.0	(18.7, 27.3)	*0.376*	*0.663*	*0.514*	*0.506*
Potential niacin (mg)	20.5	(16.4, 26.7)	20.3	(15.5, 24.2)	*0.868*	*0.255*	*0.114*	*0.320*
Vitamin B6 (mg)	2.70	(2.06, 3.28)	2.50	(2.04, 3.07)	*0.268*	*0.391*	*0.325*	*0.756*
Vitamin B12 (µg)	6.2	(4.35, 8.60)	5.9	(4.5, 8.5)	*0.981*	*0.480*	*0.138*	*0.368*
Folic acid (µg)	312	(226, 396)	355	(284, 428)	*0.019*	*<0.001*	*0.001*	*0.001*
Pantothenic acid (mg)	6.47	(4.78, 8.14)	6.08	(4.88, 7.66)	*0.855*	*0.256*	*0.052*	*0.091*
Biotin (µg)	41.8	(31.6, 52.0)	45.1	(36.4, 54.8)	*0.046*	*<0.001*	*0.004*	*0.001*
Vitamin C (mg)	167	(112, 230)	154	(118, 204)	*0.987*	*0.532*	*0.196*	*0.612*
Vitamin K (mg)	35.5	(22.6, 69.5)	69.9	(43.4, 137.2)	*<0.001*	*<0.001*	*<0.001*	*0.001*
Alcohol (g)	0.0	(0.0, 0.0)	0.0	(0.0, 2.4)	*0.007*	*0.004*	*0.025*	*0.041*

P_{25} – 25^{th} percentile, P_{75} – 75^{th} percentile;
SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids; PUFA – Polyunsaturated fatty acids
P value [1] – log-transformed, crude intakes (independent t-test)
P value [2] – log-transformed, energy-adjusted intakes (independent t-test)
P value [3] – log-transformed, crude intakes, adjusted for age, parity, ethnicity, DEPCAT, total activity (MET-hours/day), working status and gestation period (linear regression)
P value [4] – log-transformed, energy-adjusted intakes, adjusted for age, parity, ethnicity, DEPCAT, total activity (MET-hours/day), working status and gestation period (linear regression)

Table 4.2f

Median (interquartile range) of daily nutrient intakes (late pregnancy)

Nutrient	Obese (n=137)		Lean (n=68)		*P value[1]*	*P value[2]*	*P value[3]*	*P value[4]*
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})				
Energy (kcal)	2173	(1747, 2675)	2354	(1962, 2764)	*0.093*	*-*	*0.193*	*-*
Protein (g)	87.7	(69.1, 111.6)	90.1	(74.9, 117.0)	*0.141*	*0.949*	*0.193*	*0.672*
Fat (g)	87.1	(65.0, 106.4)	91.8	(72.6, 121.7)	*0.066*	*0.424*	*0.102*	*0.219*
Carbohydrate (g)	279	(227, 347)	294	(261, 352)	*0.155*	*0.529*	*0.391*	*0.169*
SFA (g)	34.8	(24.7, 43.4)	36.4	(28.3, 49.2)	*0.158*	*0.802*	*0.192*	*0.821*
MUFA (g)	29.8	(21.6, 36.6)	31.9	(24.5, 40.4)	*0.071*	*0.483*	*0.084*	*0.157*
PUFA (g)	13.9	(11.0, 18.4)	15.0	(12.8, 20.2)	*0.050*	*0.306*	*0.047*	*0.062*
Cholesterol (mg)	269	(197, 374)	255	(180, 365)	*0.884*	*0.064*	*0.306*	*0.866*
Sugars (g)	133	(99, 174)	135	(111, 178)	*0.345*	*0.453*	*0.535*	*0.393*
Starch (g)	136	(107, 175)	159	(121, 182)	*0.077*	*0.562*	*0.298*	*0.822*
Fibre (g)	19.0	(13.9, 24.3)	23.3	(19.1, 27.4)	*0.001*	*0.001*	*0.030*	*0.036*
Sodium (mg)	2926	(2298, 3526)	3239	(2646, 3897)	*0.046*	*0.265*	*0.065*	*0.121*
Potassium (mg)	3462	(2845, 4648)	3801	(3306, 4765)	*0.091*	*0.616*	*0.321*	*0.723*
Calcium (mg)	1071	(850, 1389)	1268	(1015, 1621)	*<0.001*	*<0.001*	*0.026*	*0.036*
Magnesium (mg)	359	(289, 452)	430	(360, 527)	*<0.001*	*<0.001*	*0.015*	*0.001*
Phosphorus (mg)	1652	(1274, 2097)	1753	(1529, 2215)	*0.015*	*0.017*	*0.050*	*0.025*
Iron (mg)	12.99	(10.13, 16.54	16.31	(13.63, 19.87)	*<0.001*	*<0.001*	*0.009*	*<0.001*
Copper (mg)	2.66	(2.04, 3.43)	3.24	(2.65, 4.09)	*0.004*	*0.019*	*0.047*	*0.172*
Zinc (mg)	10.9	(8.4, 13.8)	11.8	(9.8, 15.1)	*0.022*	*0.058*	*0.084*	*0.119*
Chloride (mg)	4428	(3552, 5432)	4817	(4103,5885)	*0.039*	*0.196*	*0.049*	*0.067*
Manganese (mg)	3.2	(2.6, 4.3)	4.5	(3.5, 5.7)	*<0.001*	*<0.001*	*0.004*	*0.001*
Selenium (µg)	57.5	(41, 77)	62	(51, 78)	*0.065*	*0.388*	*0.216*	*0.738*
Iodine (µg)	222	(157, 291)	249	(187, 331)	*0.020*	*0.109*	*0.055*	*0.177*
Retinol (µg)	288	(196, 428)	312	(220, 504)	*0.109*	*0.621*	*0.415*	*0.974*
B-carotene (µg)	3261	(2227, 5105)	4219	(2661, 6714)	*0.008*	*0.031*	*0.057*	*0.131*
Vitamin D (µg)	2.78	(2.02, 4.37)	4.01	(2.56, 5.80)	*0.003*	*0.015*	*0.005*	*0.011*
Vitamin E (mg)	10.02	(7.11, 13.04)	12.32	(9.03, 15.41)	*0.005*	*0.004*	*0.044*	*0.048*
Thiamine (mg)	1.76	(1.47, 2.19)	1.98	(1.62, 2.39)	*0.043*	*0.247*	*0.215*	*0.864*
Riboflavin (mg)	1.88	(1.41, 2.58)	2.23	(1.78, 2.86)	*0.001*	*0.003*	*0.026*	*0.054*
Niacin (mg)	22.4	(16.3, 28.6)	22.2	(18.0, 28.2)	*0.406*	*0.335*	*0.410*	*0.630*
Potential niacin (mg)	18.3	(14.2, 24.0)	19.3	(16.1, 25.9)	*0.094*	*0.631*	*0.100*	*0.212*
Vitamin B6 (mg)	2.46	(1.84, 3.10)	2.47	(2.05, 3.24)	*0.402*	*0.231*	*0.434*	*0.487*
Vitamin B12 (µg)	5.7	(4.0, 7.7)	6.0	(4.9, 8.6)	*0.083*	*0.441*	*0.042*	*0.122*
Folic acid (µg)	274	(202, 362)	362	(288, 432)	*<0.001*	*<0.001*	*0.015*	*0.011*
Pantothenic acid (mg)	5.68	(4.48, 7.68)	6.14	(5.13, 7.86)	*0.042*	*0.207*	*0.105*	*0.256*
Biotin (µg)	37.1	(26.9, 48.6)	44.6	(38.2, 59.3)	*<0.001*	*<0.001*	*0.006*	*0.001*
Vitamin C (mg)	147	(85.8, 197.5)	151	(111, 202)	*0.147*	*0.549*	*0.730*	*0.155*
Vitamin K (mg)	33.5	(17.4, 66.5)	62.6	(40.6, 144.5)	*<0.001*	*<0.001*	*0.002*	*0.002*
Alcohol (g)	0.0	(0.0, 0.0)	0.0	(0.0, 2.4)	*0.000*	*0.001*	*0.003*	*0.006*

P_{25} – 25th percentile, P_{75} – 75th percentile;
SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids; PUFA – Polyunsaturated fatty acids
P value [1] – log-transformed, crude intakes (independent t-test)
P value [2] – log-transformed, energy-adjusted intakes (independent t-test)
P value [3] – log-transformed, crude intakes, adjusted for age, parity, ethnic origin, DEPCAT, total activity (MET-hours/day), working status and gestation period (linear regression)
P value [4] – log-transformed, energy-adjusted intakes, adjusted for age, parity, ethnicity, DEPCAT, total activity (MET-hours/day), working status and gestation period (linear regression)

Table 4.2g

Numbers and percentages of subjects who met recommended values for nutrients

Nutrient	RNI*	Early Pregnancy				Late Pregnancy			
		Obese (n=139)		Lean (n=80)		Obese (n=137)		Lean (n=68)	
		n	%	n	%	n	%	n	%
Fibre	28g	27	19.4	22	27.5	19	13.9	15	22.1
Sodium	1500mg	133	95.7	79	98.8	130	94.9	66	97.1
Potassium	4700mg	43	29.5	20	25.0	33	24.1	18	26.5
Calcium	1000mg	100	71.9	60	75.0	78	56.9	54	79.4
Magnesium	350mg	97	69.8	67	83.8	72	52.6	54	79.4
Phosphorus	700mg	139	100.0	80	100.0	132	96.4	68	100.0
Iron	27mg	7	5.0	3	3.8	3	2.2	1	1.5
Copper	1.0mg	138	99.3	79	98.8	135	98.5	68	100.0
Zinc	11mg	84	60.4	53	66.3	68	49.6	41	60.3
Chloride	2300mg	132	95.0	79	98.8	130	94.9	67	98.5
Manganese	2.0mg	123	88.5	80	100.0	119	86.9	66	97.1
Selenium	60µg	74	53.2	48	60.0	65	47.4	40	58.8
Iodine	220µg	81	58.3	46	57.5	69	50.4	41	60.3
Vitamin D	5.0µg	27	19.4	27	33.8	25	18.2	23	33.8
Vitamin E	15mg	32	23.0	20	25.0	18	13.1	18	26.5
Thiamine	1.4mg	113	81.3	71	88.8	111	81.0	62	91.2
Riboflavin	1.4mg	111	79.9	73	91.3	104	75.9	63	92.6
Niacin	18mg	107	77.0	64	80.0	97	70.8	52	76.5
Vitamin B6	1.9mg	111	79.9	65	81.3	101	73.7	58	85.3
Vitamin B12	2.6mg	127	91.4	76	95.0	120	87.6	65	95.6
Folic acid	600µg	8	5.8	4	5.0	3	2.2	1	1.5
Pantothenic acid	6.0mg	83	60.4	43	53.8	63	46.0	37	54.4
Biotin	30µg	107	77.0	71	88.8	92	67.2	62	91.2
Vitamin C	85mg	119	85.6	77	96.3	104	75.9	63	92.6
Vitamin K	90mg	25	18.0	31	38.8	18	13.1	26	38.2

RNI - Recommended Nutrient Intakes
* Based on the dietary reference intakes for pregnant women (19-50 years), Food and Nutrition Board, Institute of Medicine (1997-2010).

4.4.2 General nutrition knowledge scores

The GNKQ was completed by 70 women from obese and 57 from lean groups. Their demographic characteristics are presented in Table 4.3. Obese group was found to have higher parity and lower DEPCAT status as well as educational attainment than lean. However, there was no significant difference between the demographic characteristics of both obese and lean groups who did or did not take part in the assessment of general nutrition knowledge (refer Appendix F).

Table 4.3

Demographic characteristics of subjects who completed General Nutrition Knowledge Questionnaire

		Obese (n=70)		Lean (n=57)		
		Mean	(Range or %)	Mean	(Range or %)	*P Value*
Age (years)		32.2	(21.0 – 44.5)	33.9	(21.1 – 42.3)	*P=0.061*‡
BMI at booking (kg/m^2)		43.8	(37.9 – 61.1)	22.4	(19.4 – 27.6)	*P<0.001*‡
Parity	Nulliparous	33	(48.5%)	38	(65.5%)	*P=0.041*†
	Multiparous	35	(51.5%)	20	(34.5%)	
Ethnicity	Caucasian	67	(97.1%)	58	(100%)	*P=0.293*†
	Non-Caucasian	2	(2.9%)			
DEPCAT status	Low	10	(14.5%)			*P<0.001*†
	Middle	52	(75.4%)	40	(69.0%)	
	High	7	(10.1%)	18	(31.0%)	
Marital status	Single	9	(13.0%)	2	(3.5%)	*P=0.110*†
	Married/With partner	60	(87.0%)	55	(96.5%)	
Educational attainment	Up until O' Level	29	(42.0%)	1	(1.8%)	*P=0.000* †
	Up until diploma	21	(30.5%)	7	(12.3%)	
	Degree or higher	19	(27.5%)	49	(86.0%)	

‡ Tested using independent t-test; † Tested using chi square test; DEPCAT – Deprivation Category

Table 4.4

Mean (standard error mean, SEM) of general nutrition knowledge scores

Scores	Obese (n=70)		Lean (n=57)		*P value* [1]	*P value* [2]
	Mean	SEM	Mean	SEM		
Section 1	8.2	0.15	8.8	0.13	*0.008*	*0.732*
Section 2	44.8	1.32	52.8	1.00	*<0.001*	*0.411*
Section 3	7.0	0.26	7.9	0.22	*0.009*	*0.786*
Section 4	7.2	0.41	10.0	0.42	*<0.001*	*0.154*
Total	67.1	1.89	78.2	1.55	*<0.001*	*0.736*

P value [1] – crude scores (independent t-test)
P value [2] – scores adjusted for age, parity, ethnicity, DEPCAT status, and education levels, (linear regression)

As demonstrated in Table 4.4, scores for each section - 1 (Healthy Recommendations), 2 (Nutrient Contents of Foods), 3 (Choosing Healthy Foods), 4 (Diet-disease Relationships) - and total scores from all four sections, were lower in obese as compared to lean in unadjusted analyses. However, these differences were no longer significant after adjusting for confounding factors including age, education levels, DEPCAT, parity, ethnicity, and gestation period (in this regression model, age and education level were significant ($P<0.01$) in determining P_{adj} values for total GNK scores, and score for each section).

General nutrition knowledge scores were not associated with total energy intake during early or late pregnancy, in either obese or lean groups (Tables 4.5a and 4.5b). In the obese group, in unadjusted analyses, total GNK scores were positively associated with almost half of the nutrients analyzed, but only associations with intakes of protein, fibre, beta carotene, selenium, and biotin remained significant after adjustment for total energy and other demographic confounding factors, in early and late pregnancy. In the lean group, after adjustment for total energy and other confounders, total GNK scores were significantly and inversely associated with intakes of total fat and SFA in early pregnancy, and positively associated with intake of fibre in late pregnancy.

Table 4.5a

Pearson correlation coefficients *(r)* between general nutrition knowledge scores and maternal reported food intake (early and late pregnancy) in obese group

Nutrient	Early Pregnancy (n=59)			Late Pregnancy (n=63)		
	r	*P value* [1]	*P value* [2]	*r*	*P value* [1]	*P value* [2]
Energy (kcal)	0.216	*0.100*	*0.058*	0.200	*0.116*	*0.656*
Protein (g)	0.269	*0.040*	*0.013*	0.251	*0.047*	*0.024*
Fat (g)	0.241	*0.066*	*0.394*	0.143	*0.262*	*0.204*
Carbohydrate (g)	0.169	*0.201*	*0.098*	0.214	*0.092*	*0.078*
SFA (g)	0.184	*0.164*	*0.965*	0.097	*0.449*	*0.441*
MUFA (g)	0.247	*0.059*	*0.585*	0.130	*0.309*	*0.309*
PUFA (g)	0.261	*0.046*	*0.110*	0.171	*0.181*	*0.939*
Cholesterol (mg)	0.149	*0.262*	*0.164*	0.114	*0.373*	*0.072*
Sugars (g)	0.134	*0.311*	*0.696*	0.200	*0.116*	*0.126*
Starch (g)	0.189	*0.151*	*0.110*	0.201	*0.115*	*0.901*
Fibre (g)	0.356	*0.006*	*0.043*	0.373	*0.003*	*0.032*
Sodium (mg)	0.279	*0.032*	*0.142*	0.162	*0.204*	*0.735*
Potassium (mg)	0.263	*0.044*	*0.163*	0.259	*0.041*	*0.591*
Calcium (mg)	0.181	*0.170*	*0.619*	0.146	*0.255*	*0.084*
Magnesium (mg)	0.314	*0.015*	*0.225*	0.255	*0.044*	*0.713*
Phosphorus (mg)	0.231	*0.078*	*0.311*	0.231	*0.068*	*0.282*
Iron (mg)	0.308	*0.017*	*0.735*	0.314	*0.012*	*0.363*
Copper (mg)	0.223	*0.090*	*0.441*	0.007	*0.954*	*0.233*
Zinc (mg)	0.320	*0.014*	*0.094*	0.300	*0.017*	*0.461*
Chloride (mg)	0.255	*0.051*	*0.197*	0.139	*0.277*	*0.280*
Manganese (mg)	0.409	*0.001*	*0.283*	0.378	*0.002*	*0.129*
Selenium (µg)	0.275	*0.035*	*0.092*	0.295	*0.019*	*0.905*
Iodine (µg)	0.107	*0.419*	*0.515*	0.166	*0.194*	*0.167*
Retinol (µg)	0.106	*0.423*	*0.051*	0.135	*0.292*	*0.242*
B-carotene (µg)	0.312	*0.016*	*0.002*	0.444	*<0.001*	*<0.001*
Vitamin D (µg)	0.203	*0.044*	*0.053*	0.298	*0.018*	*0.778*
Vitamin E (mg)	0.297	*0.022*	*0.033*	0.272	*0.031*	*0.406*
Thiamine (mg)	0.272	*0.037*	*0.183*	0.264	*0.037*	*0.361*
Riboflavin (mg)	0.130	*0.328*	*0.734*	0.116	*0.364*	*0.085*
Niacin (mg)	0.242	*0.065*	*0.261*	0.252	*0.046*	*0.984*
Potential niacin (mg)	0.259	*0.048*	*0.059*	0.223	*0.079*	*0.320*
Vitamin B6 (mg)	0.191	*0.147*	*0.736*	0.236	*0.063*	*0.987*
Vitamin B12 (µg)	0.154	*0.245*	*0.148*	0.229	*0.070*	*0.882*
Folic acid (µg)	0.281	*0.031*	*0.152*	0.299	*0.017*	*0.653*
Pantothenic acid (mg)	0.256	*0.050*	*0.327*	0.235	*0.064*	*0.239*
Biotin (µg)	0.398	*0.002*	*0.015*	0.274	*0.030*	*0.885*
Vitamin C (mg)	0.225	*0.087*	*0.616*	0.316	*0.012*	*0.310*
Vitamin K (µg)	0.421	*0.001*	*0.102*	0.459	*<0.001*	*0.168*
Alcohol	-0.073	*0.585*	*0.539*	-0.041	*0.752*	*0.449*

P value [1] – log-transformed data
P value [2] – log-transformed data adjusted for total energy, age, parity, ethnicity, DEPCAT status, and education level

Table 4.5b

Pearson correlation coefficients *(r)* between general nutrition knowledge scores and maternal reported food intake (early and late pregnancy) in lean group

Nutrient	Early Pregnancy (n=54)			Late Pregnancy (n=53)		
	r	*P value* [1]	*P value* [2]	*r*	*P value* [1]	*P value* [2]
Energy (kcal)	-0.087	*0.532*	*0.078*	0.076	*0.586*	*0.663*
Protein (g)	-0.145	*0.295*	*0.685*	-0.033	*0.817*	*0.126*
Fat (g)	-0.176	*0.204*	*0.039*	-0.021	*0.883*	*0.087*
Carbohydrate (g)	0.043	*0.758*	*0.809*	0.107	*0.137*	*0.120*
SFA (g)	-0.155	*0.263*	*0.025*	0.035	*0.804*	*0.213*
MUFA (g)	-0.208	*0.131*	*0.074*	-0.046	*0.744*	*0.060*
PUFA (g)	-0.227	*0.098*	*0.096*	0.001	*0.993*	*0.225*
Cholesterol (mg)	-0.101	*0.468*	*0.515*	-0.157	*0.262*	*0.041*
Sugars (g)	0.004	*0.978*	*0.464*	0.156	*0.265*	*0.324*
Starch (g)	0.078	*0.573*	*0.512*	0.176	*0.208*	*0.186*
Fibre (g)	0.086	*0.539*	*0.878*	0.270	*0.050*	*0.031*
Sodium (mg)	-0.060	*0.666*	*0.542*	0.080	*0.571*	*0.614*
Potassium (mg)	-0.059	*0.670*	*0.878*	0.132	*0.345*	*0.722*
Calcium (mg)	-0.086	*0.534*	*0.799*	0.146	*0.298*	*0.581*
Magnesium (mg)	-0.035	*0.800*	*0.512*	0.203	*0.145*	*0.092*
Phosphorus (mg)	-0.092	*0.509*	*0.932*	0.119	*0.398*	*0.778*
Iron (mg)	0.007	*0.959*	*0.155*	0.165	*0.238*	*0.340*
Copper (mg)	0.005	*0.972*	*0.752*	0.115	*0.414*	*0.385*
Zinc (mg)	-0.057	*0.680*	*0.508*	0.042	*0.763*	*0.543*
Chloride (mg)	-0.087	*0.534*	*0.888*	0.087	*0.537*	*0.619*
Manganese (mg)	0.087	*0.532*	*0.164*	0.253	*0.067*	*0.242*
Selenium (µg)	-0.233	*0.090*	*0.149*	-0.088	*0.532*	*0.145*
Iodine (µg)	-0.117	*0.400*	*0.341*	-0.023	*0.868*	*0.648*
Retinol (µg)	-0.142	*0.304*	*0.232*	-0.016	*0.907*	*0.341*
B-carotene equivalent (µg)	-0.036	*0.794*	*0.338*	0.071	*0.616*	*0.475*
Vitamin D (µg)	-0.029	*0.715*	*0.540*	-0.148	*0.291*	*0.167*
Vitamin E (mg)	-0.081	*0.532*	*0.941*	0.086	*0.539*	*0.180*
Thiamine (mg)	-0.072	*0.605*	*0.493*	0.077	*0.582*	*0.896*
Riboflavin (mg)	-0.112	*0.421*	*0.727*	0.054	*0.701*	*0.700*
Niacin (mg)	-0.199	*0.149*	*0.706*	-0.008	*0.956*	*0.573*
Potential niacin (mg)	-0.157	*0.257*	*0.406*	-0.095	*0.498*	*0.332*
Vitamin B6 (mg)	-0.144	*0.298*	*0.998*	0.122	*0.385*	*0.626*
Vitamin B12 (µg)	-0.261	*0.057*	*0.148*	-0.144	*0.304*	*0.162*
Folic acid (µg)	-0.040	*0.772*	*0.543*	0.157	*0.262*	*0.617*
Pantothenic acid (mg)	-0.059	*0.670*	*0.633*	0.069	*0.626*	*0.656*
Biotin (µg)	-0.018	*0.898*	*0.871*	0.180	*0.197*	*0.500*
Vitamin C (mg)	-0.003	*0.985*	*0.182*	0.114	*0.415*	*0.786*
Vitamin K (µg)	-0.236	*0.085*	*0.269*	-0.128	*0.362*	*0.337*
Alcohol	-0.010	*0.942*	*0.401*	0.057	*0.684*	*0.695*

P value [1] – log-transformed data
P value [2] – log-transformed data adjusted for total energy, age, parity, ethnicity, DEPCAT status, and education level

4.4.3 Appetite scores

61 obese and 41 lean women completed the CNAQ during early pregnancy and 58 obese and 40 lean women completed it during late pregnancy. Their demographic characteristics are presented in Table 4.6. Obese group was slightly but significantly younger, and of lower DEPCAT status, compared to lean. However, there was no significant difference between the demographic characteristics of both obese and lean groups who did or did not take part in the assessment of appetite (refer Appendix G).

Table 4.6

Demographic characteristics of subjects who completed Council on Nutrition Appetite Questionnaire

		Obese (n=71)		Lean (n=57)		
		Mean	(Range or %)	Mean	(Range or %)	*P Value*
Age (years)		30.8	(19.8 – 43.3)	33.8	(21.1 – 42.3)	*P=0.001*‡
BMI at booking (kg/m^2)		44.8	(38.1 – 61.1)	22.7	(19.4 – 27.6)	*P<0.001*‡
Parity	Nulliparous	34	(47.9%)	33	(63.1%)	*P=0.289*†
	Multiparous	37	(52.1%)	24	(36.9%)	
Ethnicity	Caucasian	68	(95.8%)	84	(100%)	*P=0.253*†
	Non-Caucasian	3	(4.2%)			
DEPCAT index	Low (1 to 2)	8	(11.3%)			*P<0.001*†
	Middle (3 to 5)	57	(80.3%)	39	(68.4%)	
	High (6 to 7)	6	(8.6%)	18	(31.6%)	

‡ Tested using independent t-test; † Tested using chi square test; DEPCAT – Deprivation Category

There were no significant changes in the total CNAQ scores from early to late pregnancy in both obese and lean groups (Table 4.7a), and this was similar in paired data groups (Table 4.7b). The obese group reported lower total scores than the lean ($P_{adj} \leq 0.001$) during early and late pregnancy (Table 4.7c). Reported appetite scores were not correlated with total energy intake in either obese (early pregnancy, r=0.235, $P_{adj}=0.167$; late pregnancy, r=0.164, $P_{adj}=0.688$) or lean (early pregnancy, r=0.021, $P_{adj}=0.904$; late pregnancy, r=0.204, $P_{adj}=0.195$) groups.

Table 4.7a

Mean (standard error mean, SEM) of total appetite scores between early and late pregnancy

	Early Pregnancy			Late Pregnancy			*P value*[1]	*P value*[2]
	n	Mean	SEM	n	Mean	SEM		
Obese	61	20.7	0.43	58	20.6	0.45	*0.933*	*0.911*
Lean	41	23.3	0.31	40	23.8	0.31	*0.249*	*0.260*

P value [1] – unadjusted scores (independent t-test)
P value [2] – scores adjusted for age, parity, ethnicity, and DEPCAT status (linear regression)

Table 4.7b

Mean (standard error mean, SEM) of total appetite scores for paired data

		Early Pregnancy		Late Pregnancy		*P value*
	n	Mean	SEM	Mean	SEM	
Obese	37	20.1	0.57	20.2	0.58	*0.674*
Lean	24	23.0	0.42	23.8	0.34	*0.057*

P value – unadjusted scores (paired t-test)

Table 4.7c

Mean (standard error mean, SEM) of total appetite scores between obese and lean groups

	Obese			Lean			*P value*[1]	*P value*[2]
	n	Mean	SEM	n	Mean	SEM		
Early pregnancy	61	20.7	0.43	41	23.3	0.31	*<0.001*	*0.001*
Late pregnancy	58	20.6	0.45	40	23.8	0.31	*<0.001*	*<0.001*

P value [1] – unadjusted scores (independent t-test)
P value [2] – scores adjusted for age, parity, ethnicity, and DEPCAT status (linear regression)

4.4.4 Eating behaviour scores

A total of 85 women (48 obese and 37 lean) completed the DEBQ. Their demographic characteristics were presented in Table 4.8. Obese group was slightly but significantly younger, and also of lower DEPCAT status, compared to lean. However, the demographic characteristics of both obese and lean participants who did or did not take part in the assessment of eating behaviour were not significantly different (refer Appendix H).

Table 4.8

Demographic characteristics of subjects who completed the Dutch Eating Behaviour Questionnaire

		Obese (n=48)		Lean (n=37)		
		Mean	(Range or %)	Mean	(Range or %)	*P Value*
Age (years)		30.7	(19.8 – 40.2)	34.1	(24.1 – 41.3)	*P=0.001*‡
BMI at booking (kg/m^2)		43.8	(37.9 – 61.1)	22.4	(19.4 – 27.6)	*P<0.001*‡
Parity	Nulliparous	21	(43.8%)	24	(64.9%)	*P=0.053*†
	Multiparous	27	(56.2%)	13	(35.1%)	
Ethnicity	Caucasian	45	(93.8%)	37	(100%)	*P=0.122*†
	Non-Caucasian	3	(6.2%)			
DEPCAT status	Low	5	(10.4%)			*P=0.044*†
	Middle	37	(77.1%)	27	(73.0%)	
	High	6	(12.5%)	10	(27.0%)	

‡ Tested using independent t-test; † Tested using chi square test; DEPCAT – Deprivation Category

Table 4.9

Mean (standard error of mean, SEM) of mean eating behaviour scores

Section	Obese (n=48)		Lean (n=37)		*P value*[1]	*P value*[2]
	Mean	SEM	Mean	SEM		
Restraint eating	2.7	0.09	2.4	0.10	*0.008*	*0.002*
Emotional eating	2.5	0.11	2.2	0.11	*0.023*	*0.026*
Externally cued eating	2.8	0.08	3.0	0.07	*0.063*	*0.488*

P value [1] – unadjusted scores (independent t-test)
P value [2] – scores adjusted for age, parity, ethnicity, and DEPCAT status (linear regression)

The restraint and emotional eating scores were significantly higher in obese, as compared to lean (Table 4.9). There was no significant difference in the externally-cued eating scores between the two groups.

Pearson correlation coefficient was used to test the association between eating behaviour scores and intakes of total energy and macronutrients (protein, fat and carbohydrate). In obese, the restraint eating mean score was not associated with intakes of total energy or any micronutrients (Table 4.10a). The emotional eating mean score was positively associated with total energy intake during late pregnancy but this was no longer significant after adjusting for confounding factors. There was a trend for a similar association in early pregnancy but this did not reach statistical significance. The externally-cued eating mean score was positively associated with total energy and fat intakes, and inversely correlated with carbohydrate intakes, both during early and late pregnancy. In lean, the only significant correlation found was with regard to externally-cued eating mean score, which was positively associated with fat intakes during both early and late pregnancy (Table 4.10b).

Table 4.10a

Pearson correlation coefficients between mean eating behaviour scores and maternal reported total energy and macronutrients intakes (early and late pregnancy) in obese group

	Restraint eating			Emotional eating			Externally cued eating		
	r	*P value*[1]	*P value*[2]	r	*P value*[1]	*P value*[2]	r	*P value*[1]	*P value*[2]
Early pregnancy	**(n=42)**								
Energy (kcal)	-0.017	*0.917*	*0.797*	0.293	*0.060*	*0.065*	0.457	*0.002*	*0.004*
Protein (g)*	0.083	*0.600*	*0.420*	0.078	*0.624*	*0.228*	0.116	*0.463*	*0.404*
Fat (g)*	0.201	*0.201*	*0.233*	-0.058	*0.716*	*0.994*	0.391	*0.011*	*0.022*
Carbohydrate (g)*	-0.266	*0.088*	*0.082*	0.054	*0.734*	*0.888*	-0.330	*0.033*	*0.036*
Late pregnancy	**(n=36)**								
Energy (kcal)	-0.090	*0.603*	*0.962*	0.340	*0.043*	*0.363*	0.340	*0.043*	*0.045*
Protein (g)*	0.280	*0.098*	*0.120*	0.208	*0.223*	*0.124*	0.265	*0.118*	*0.132*
Fat (g)*	0.037	*0.829*	*0.851*	0.008	*0.963*	*0.221*	0.304	*0.041*	*0.022*
Carbohydrate (g)*	-0.136	*0.430*	*0.425*	-0.085	*0.621*	*0.103*	-0.349	*0.037*	*0.011*

* Adjusted for total energy
P value [1] – log-transformed data
P value [2] – log-transformed data adjusted for age, parity, ethnicity, and DEPCAT status

Table 4.10b

Pearson correlation coefficients between mean eating behaviour scores and maternal reported total energy and macronutrients intakes (early and late pregnancy) in lean group

	Restraint eating			Emotional eating			Externally cued eating		
	r	*P value*[1]	*P value*[2]	r	*P value*[1]	*P value*[2]	r	*P value*[1]	*P value*[2]
Early pregnancy	**(n=36)**								
Energy (kcal)	-0.033	*0.847*	*0.685*	-0.097	*0.574*	*0.417*	0.159	*0.355*	*0.850*
Protein (g)*	-0.020	*0.906*	*0.782*	0.259	*0.127*	*0.140*	-0.036	*0.835*	*0.783*
Fat (g)*	0.223	*0.192*	*0.352*	0.280	*0.098*	*0.181*	0.430	*0.009*	*0.023*
Carbohydrate (g)*	-0.174	*0.310*	*0.520*	-0.328	*0.051*	*0.092*	-0.250	*0.141*	*0.253*
Late pregnancy	**(n=25)**								
Energy (kcal)	-0.032	*0.879*	*0.870*	-0.006.	*0.979*	*0.998*	0.353	*0.083*	*0.088*
Protein (g)*	-0.046	*0.828*	*0.942*	0.250	*0.229*	*0.203*	-0.024	*0.908*	*0.983*
Fat (g)*	-0.195	*0.350*	*0.663*	0.091	*0.666*	*0.477*	0.446	*0.025*	*0.036*
Carbohydrate (g)*	0.176	*0.400*	*0.753*	-0.181	*0.386*	*0.979*	-0.379	*0.062*	*0.345*

* Adjusted for total energy
P value [1] – log-transformed data
P value [2] – log-transformed data adjusted for age, parity, ethnicity, and DEPCAT status

4.5 Discussion

The main aim of this chapter was to examine the dietary intake of severely obese women during pregnancy and to compare it to the intake of their lean counterparts. Overall there were no significant differences in the reported total energy intake between obese and lean groups throughout pregnancy. However, the obese group did report a reduction in their total energy intake from early to late pregnancy. The diets of obese women were generally of poorer quality as they contained significantly less dietary fibre and important nutrients during pregnancy including calcium, iron, vitamin D and folic acid, compared to lean women. Furthermore, a higher percentage of the obese group participants did not meet the RNIs set for these nutrients. The obese group also reported significantly lower appetite, higher restraint and emotional eating scores than lean. General nutrition knowledge scores did not differ between obese and lean after adjustment for possible confounding factors. None of these had any effect on total energy intake in either group. Only externally-cued eating behaviour scores were correlated with total energy intake in obese.

In the UK, the dietary intake of pregnant women has been described in a small number of studies. A survey in the south west of England found that the dietary intake of pregnant women was comparable with the intakes in non-pregnant women, except for lower total energy, iron, magnesium, potassium and folate (Godfrey et al, 1996). This study, which included 538 pregnant women, used a similar method to the current study (food frequency questionnaire) for food intake data collection. They reported median total energy intakes of 2,329 kcal in early pregnancy and 2,314 kcal in late pregnancy. These, and their values for macronutrients (protein, fat and carbohydrate), sugars, iron and folic acid (from food and supplements), were generally comparable to the values reported by our lean controls. Another cohort study with 693 pregnant participants (Mathews, Yudkin and Neil, 1999) reported lower median intake of total calories (2,044kcal early pregnancy; 2,197 late pregnancy), and iron and folic acid (from food only) than ours. This study used a 7-day food diary (FD) as their main method of dietary assessment which may explain why they found lower values. It has been previously demonstrated that nutrient intakes reported by pregnant women using a FD are generally lower than using FFQ methods (Brantsaeter et al, 2008, Errkola et al, 2001, Robinson et al, 1996). Likewise, reported intakes were less using FD than FFQ in the subgroup of women who completed the validation study (Chapter 3).

A large cohort study in England (n=11,923) reported much lower mean total energy intake of 1,823kcal, and also of other micronutrients (from both food and supplements) during week 32 of pregnancy (Rogers and Emmett, 1998) than our study. These results were not directly comparable to the current study because they used self-reported ‘unquantified’ FFQ where no information was collected about portion sizes (and standard portion sizes were therefore used for analysis purposes). Their results also did not include alcohol consumption. Despite these limitations, Rogers and Emmett also found that the reported daily intakes of iron, magnesium, potassium and folic acid in their study population were below the recommended intakes for pregnancy. The same questionnaire used by Rogers and

Emmett was administered by an interviewer in a more recent study in 250 pregnant women during early pregnancy (Mouratidou et al, 2006a). They also found lower total calories (mean 1,863kcal) than the current study but a similar trend of inadequate intakes of nutrients such as calcium, iron and folic acid (Mouratidou et al, 2006a).

All of the cohort studies investigating food intake during pregnancy discussed above were carried out amongst the general population of pregnant women. There are no previous studies focusing on obese pregnancy, apart from interventional studies with a smaller number of participants. A randomized-controlled study (Guelinckx et al, 2010) which looked at the effect of lifestyle intervention on dietary habits, physical activity and gestational weight gain in obese pregnant women (BMI >30), allocated study participants into 1 of 3 different groups (passive group- given a nutritional brochure; active group- given nutritional brochure and lifestyle education from a nutritionist; control group). Food intake was assessed using a 7-day FD in each trimester. Guelinckx et al (2010) reported that their active group (n=42) did not significantly change their diets throughout pregnancy although there was a pattern for an increment of total energy intake between first, second and third trimester (mean 1,880, 1,826 and 1,917 kcal). This finding was totally opposite to the reduction in calories from early to late pregnancy reported by the obese group in our study. However, our study had almost three times the number of participants (paired data, n=114) compared to Guerlinckx et al's study. It is also yet to be determined if the reduction of calories during pregnancy in our study population is due to actual reduction of food intake, or due to under-reporting. This will be investigated in Chapter 5 of this thesis. In addition, all obese women participating in this research study received tailored advice about healthy eating in pregnancy, and it is not known whether this has influenced their food choices.

Despite reporting similar total calorie intake to their lean counterparts, the highly inadequate intake of micronutrients in our obese group is of particular concern. On average, only 3-4% of the obese women met the RDAs for iron and folic acid, and less than 25% for vitamin D, vitamin E, vitamin K and potassium. Similar patterns have been reported in the general pregnant women population in the UK (Godfrey et al, 1996, Rogers and Emmett, 1998, Mouratidou et al, 2006a, Derbyshire et al, 2009). Apart from folic acid and iron, the micronutrient inadequacy was more pronounced in our obese compared to lean group. The importance of these micronutrients in influencing pregnancy outcomes is well recognised and their deficiencies can have a profound effect on development of fetal tissues and organs and may also affect health status of infants in the long-term (Ashworth and Antipatis, 2001). Poor folic acid intake during pregnancy is one of the maternal risk factors for neural tube defects in babies (Herrmann and Obeid, 2011). Both folate and vitamin D deficiencies may increase risks of pre-eclampsia, preterm delivery, low birth weight and fetal growth restrictions (Tamura and Picciano, 2006, Bodnar et al, 2007). Low vitamin D status is also associated with physical anomalies such rickets and skeletal malformations (Bodnar et al, 2007). Iron deficiency is known to cause anaemia during pregnancy (Black, 2003). The fact that these detrimental birth outcomes caused by micronutrient deficiencies, are also closely associated with maternal obesity, deserves attention. The presence of nutritional deficiencies in obese individuals may seem paradoxical in light of the overnutrition state but it has been documented that several micronutrients are deficient in overweight and obese non-pregnant individuals, particularly those who are severely obese (BMI ≥40) such as the women in our study population (Xanthakos, 2009). The cause is not fully known, but it may largely be due to poor quality diet such as increased consumption of highly processed foods which are rich in calories but poor in nutrient density, and this proportionally reduces the intake of healthier, more nutritious foods (Xanthakos, 2009). Increased adiposity itself is associated with lower serum levels of some fat-soluble nutrients, such as vitamin D, and this predicts poor status of this nutrient during pregnancy (Bodnar et al, 2007).

General nutrition knowledge scores from GNKQ (Parmenter and Wardle, 1999) were initially found to be lower in obese than lean, but these were no longer significant after adjusting for age and education levels. Nutrition knowledge assessed in 1,040 adults using the same questionnaire was found to be significantly associated with higher intake of fruits and vegetables and less fat, and the effect persisted after controlling for demographic variables (Wardle, Parmenter and Waller, 2000). In the current study, total GNK scores were found to significantly increase with increasing intakes of protein, fibre, beta carotene, selenium and biotin in obese group, and with decreasing intakes of total fats and SFA and increasing intakes of fibre in lean. Our obese participants were significantly younger and had lower education levels than their lean counterparts. Other than socioeconomic status, educational attainment has been documented by others to have a strong influence on nutrition knowledge (Parmenter, Waller and Wardle, 2000) and diet quality during pregnancy (Robinson et al, 2004).

An appetite-monitoring instrument (CNAQ) was used in this study to assess appetite, hunger, food taste, experience of nausea/sickness during meals, amount of foods required to feel full and number of meals eaten per day during pregnancy (Wilson et al, 2005). The obese group reported significantly lower total scores than lean during both early and late pregnancy. The scores for the question that specifically asks about appetite ("My appetite is..") were similar between obese and lean groups (average to good), but obese generally scored lower for other questions which suggested that they felt hungry less often, they needed to eat smaller amount of food to feel full, food tasted less good, they ate fewer meals in a day and they experienced more nausea/sickness during mealtimes, as compared to the lean group. There is little literature about appetite assessment in obese pregnancy. Eating behaviour assessment in severely obese individuals (n=552) who were undergoing bariatric surgery demonstrated that respondents attributed their excess weight to eating in response to negative/positive affect and social cues, general overeating, impaired appetite regulation, and snacking (Fabricatore et al, 2006). The fact that obese subjects in the current study reported similar appetites to lean but needed less food to feel full and reported eating less number of meals per day than lean may be associated with genuinely better satiety in obese or may be influenced by misreporting of true information.

Abnormal dietary behaviour has been implicated in the development of obesity in general (nonpregnant) women populations and the risk factors include both opposite ends of the spectrum; dieting/ restrained eating as well as disinhibition/binge eating (van der Merwe, 2007). Assessment of 3 inter-related psychological dimensions of eating behaviours in our study population has revealed that obese women have higher scores associated with restraint (conscious determination to restrict food intake) and emotional (inclination to eat in response to negative emotions such as depression) eating behaviours as compared to lean. Both dietary restraint and emotional eating has been shown to be the moderator of the relationship between overconsumption and increased weight in general adult populations (van Strien, Herman, and Verheijden, 2009) and is significantly positively associated with BMI (Nolan, Halperin and Geliebter, 2010). In women, a longitudinal study assessing dietary restraint prior to pregnancy found that subjects of greater pre-pregnancy weight scored higher on the dietary restraint measure (Conway et al, 1999) and this trend was continued during pregnancy (Laraia et al, 2009). In the current study, the scores for external eating (tendency to eat more in response to environmental food cues such as foods sight, smell and taste) were not significantly different between both groups, but were significantly associated with increased intakes of total energy and energy-adjusted total fat as well as reduced intake of energy-adjusted total carbohydrate in obese, and with increased energy-adjusted total fat intake in lean. A study in non-pregnant women demonstrated that external eating behaviour was consistently positively related to total energy intake as well as total fat and carbohydrate intakes (Anschutz et al, 2009). This study, however, did not adjust the macronutrients intakes for total energy and this might explain the different finding from ours with regard to total carbohydrate intake.

One of the limitations of this study is the use of self-reported questionnaires for information collection. The use of this method is highly dependent on individuals' recall ability, personal perception and interpretation of what is being asked. However, this has to be balanced against the alternative of using an interviewer-administered questionnaire which may be subjected to under- or overestimation due to response-bias effect which occurs when a subject feels pressurized to give socially-desirable answers, particularly in female and higher BMI populations (Lissner, 2002). The extent to which subjects participating in this study mis-reported food intake using the questionnaire is explored in the following chapter.

CHAPTER 5

Misreporting of total energy intake

Chapter 5

5.1 Introduction

It is a challenge to accurately measure dietary intake in human population studies. Self-reported dietary assessment, which is the most extensively used in population studies, is subject to a considerable amount of measurement error. It has been widely reported that total energy and nutrient intakes are commonly under-reported and this occurs more frequently in overweight and female subjects (Poslusna et al, 2009, Ferrari et al, 2002). In the current study population, severely obese women reported to be consuming similar total energy intake to lean both during early and late pregnancy (as discussed in Chapter 4 of this thesis), and it was postulated that inaccuracy of reporting may underlie this finding.

Misreporting may be done deliberately or subconsciously. It may involve under-reporting, where there is a discrepancy between reported energy intake and measured energy expenditure, without any change in body mass. It may also be due to under-eating, where subjects actually eat less than required for weight maintenance, and this is accompanied by a decline in body mass (Scagliusi et al, 2003, Hill and Davies, 2001). Reporting of implausibly low energy intake may occur through several ways; respondents failing to accurately recall the foods and estimate the portion sizes, respondents deliberately choosing not to report all foods eaten (Hill and Davies, 2001), or respondents only reporting some of the foods eaten due to inconvenience of having to record everything that was eaten (Scagliusi et al, 2003).

Social-desirability bias is believed to be a relevant factor particularly when considering the prevalence of measurement errors in the overweight population. There is a tendency to supply answers to dietary questions that place the respondents in what is perceived to be a favourable light (Lissner, 2002). Hence, foods rich in fat and/or refined sugar which may be perceived as socially undesirable are often under-reported more than healthy foods (Livingstone and Black, 2003).

Reporting of physiologically implausible energy intakes has also been shown to be prevalent in pregnant women populations (Forsum and Lof, 2007, Derbyshire et al, 2006, Goldberg et al, 1993). The prevalence of misreporting in severely obese pregnant women, however, has yet to be studied.

5.2 Aim(s)

The aims of this chapter were to assess:

a) reporting accuracy (under-, adequate and over-reporting) of self-reported energy intake
b) prevalence of implausible energy intake reporting according to different maternal characteristics
c) nutrient density of self-reported diets according to categories of reporting accuracy (under-, adequate and over-reporting)

in obese and lean pregnant women who were enrolled in the Energy Balance in Pregnancy (EBIP) study at the Antenatal Metabolic Clinic.

5.3 Methods

5.3.1 Study design

This was a case-control study comparing obese and lean pregnant women who were recruited among participants from a larger prospective cohort study.

5.3.2 Ethical approval

The EBIP study was approved by the Lothian NHS Research Ethics Committee and all subjects gave written informed consent.

5.3.3 Subjects recruitment

Participants for EBIP study were recruited from August 2008 until August 2011 (for details refer section 2.1.4.2). All participants who had their weights measured during first visit to the clinic (before or at week 20) and had completed the Scottish Collaborative Group Food Frequency Questionnaire (SCG-FFQ) and Pregnancy Physical Activity Questionnaire (PPAQ) during late pregnancy (week 28-30 of gestation) were included in this study. Only data from women who first presented to the clinic before or at 20 weeks gestation and attended their 28-week visit were included in this study since early pregnancy weights were required in the estimation of energy requirement.

5.3.4 Weight and height measurement

Weight in kilograms (kg) was measured during first visit to the clinic using a SECA 959 chair weighing scale (SECA Ltd, Birmingham, UK) as detailed in Section 2.4.3. Since pre-pregnancy weight data were not available, weights at 12-weeks were imputed by calculating the average weekly weight changes between first visit and week 20 from all participants in each obese and lean group. The average gestational weight change rates obtained was 0.31kg/week for obese and 0.52kg/week for lean. This value was multiplied with the difference in number of weeks between first visit and 12 weeks for each person. The total weight change (in kg) was then subtracted from/added to the weight measured at the first visit in order to derive the imputed weight at 12-weeks. This imputed weight was used in the calculation of estimated energy requirement (EER).

Height (in centimetres) was measured during the first visit using a SECA stadiometer (SECA Ltd, Birmingham, UK) as detailed in Section 2.4.3.

5.3.5 Energy intake

Food intake was measured using a validated, semi-quantitative SCG-FFQ version 6.6 (Scottish Collaborative Group, University of Aberdeen, UK). The SCG-FFQ was completed twice; during the first and 28-week visits (details are presented in chapter 4). The energy intake (EI) used to compute EI:EER ratio was obtained from SCG-FFQ completed at 28-weeks.

5.3.6 Estimated energy requirement

The EER for each person was calculated using the Dietary Reference Intake equations which are age and sex-specific and are based on age (calculated from date of birth), weight, height and physical activity level, PAL (female adult equation for lean group, and female overweight or obese 19 years or older equation for obese group, Institute of Medicine (IOM), 2002, refer Appendix W). The Dietary Reference Intake equations also recommend an additional adjustment in pregnancy of 340kcal (IOM, 2002) which is the average energy cost of pregnancy during the second trimester for the general pregnant women population. However, research has demonstrated that total energy expenditure during pregnancy is dependent on pre-pregnancy BMI. Butte et al (2004) found that energy costs measured using doubly-labelled water (DLW) technique during the 2^{nd} trimester of pregnancy were 163, 356, and 441kcal/day in pregnant women who were underweight, normal-weight, and overweight (BMI $\geq$26.0), respectively. Therefore these values for normal and overweight individuals were used in this study.

The PAL for use with the Dietary Reference Intake equations was categorized into sedentary, moderately active, and active. Each has its corresponding physical activity coefficient. The individual PAL for the study participants was determined using self-reported sports/exercise activity expenditure (MET-hours/week) using the PPAQ completed during the first visit (details of which are presented in Chapter 6 of this thesis), Participants were categorised using cut-off values of the minimum (16 MET-hours/week) and preferable (28 MET-hours/week) amounts of physical activity expenditure as recommended by American College of Sports Medicine and American Heart Association for pregnant women without medical or obstetric complications for optimal health benefits during pregnancy (Zavorsky and Longo, 2011).

5.3.7 Determination of energy intake: estimated energy requirement (EI:EER) ratio

To determine the degree of reporting accuracy for each person, the EI:EER ratio was calculated using total energy intake (kcal/day) as reported in the SCG-FFQ completed during the 28-week visit, divided by the EER. Each person was then categorized as an 'under-reporter', 'adequate reporter', or 'over-reporter' using cut off-points for lean (under-reporting EI:EER<0.73, adequate reporting 0.73≤EI:EER≥1.27, over-reporting EI:EER>1.27) and obese (under-reporting EI:EER<0.72, adequate reporting 0.72≤ EI:EER ≥1.28, over-reporting EI:EER>1.28) as published by Nowicki et al (2011).

5.3.8 Maternal characteristics

Information including age, parity, deprivation category based on postcode (DEPCAT), smoking and alcohol intake, were obtained from personal background and lifestyle questionnaires completed by participants during the first visit.

Gestational weight gain (GWG) was computed as the difference between weights measured during the first and 36-weeks visits. This was then compared with the BMI-specific guidelines recommended by the IOM (Rasmussen and Yaktine, 2009, refer Table 1.1) to determine inadequate, adequate, or excess GWG.

Levels of nutrition knowledge in study participants were evaluated by using a validated General Nutrition Knowledge Questionnaire (Parmenter and Wardle, 1999). This questionnaire contains 4 sections; dietary recommendations, food sources, food choices, and diet disease relationship (details are presented in Section 2.5.3).

The Council on Nutrition Appetite Questionnaire (Wilson et al, 2005) was administered to assess appetitive characteristics such as perceived levels of appetite, hunger, food taste, amount of food required to feel full, and number of meals eaten in a day, in study participants (details are presented in Section 2.5.4).

The Dutch Eating Behaviour Questionnaire (van Strien et al, 1986) was administered to assess three psychological dimensions of eating behaviour namely restraint, emotional, and externally-cued eating behaviour (details are presented in Section 2.5.5).

The Hospital Anxiety and Depression Scale (HADS) questionnaire (Zigmond and Snaith, 1983) was administered to assess anxiety and depression. This contains an anxiety and a depression subscale, each comprised of 7 items. Life satisfaction was measured as a cognitive-judgmental process by using the Satisfaction with Life Scale, SWLS (Diener et al, 1985), a five-item questionnaire. Each item comes with a seven-point rating scale, ranging from 'strongly disagree' to 'strongly agree'.

5.3.9 Statistical methods

Normal distribution of data was assessed visually using histograms and Q-Q plots, and by using Kolmogorov-Smirnov test. Some nutrient intakes were not normally distributed and were normalized using natural log-transformation (total energy, polyunsaturated fatty acids, calcium, copper, selenium, beta carotene, vitamin D, vitamin B12, folic acid, vitamin K and alcohol).

Nutrient density was calculated as nutrient content in diet per 1,000kcal. Nutrient intakes from dietary supplements were not included in any of the analyses.

Values of energy intake, EI:EER, under-reporting, adequate reporting and over-reporting, were compared across maternal characteristics and significance level was tested using independent samples t-test or analysis of variance (ANOVA) F test. Some maternal characteristics (physical activity (PA) at 28 weeks gestation, appetite, nutrition knowledge, satisfaction with life, anxiety and depression) were included as post-hoc analyses as data were not available for all participants. Whether or nor subjects met PA guidelines was determined by using the minimum target for activity energy expenditure of 16 MET-hours/week as recommended by American College of Sports Medicine and American Heart Association for healthy pregnancy (Zavorsky and Longo, 2011). Participants were ranked into tertiles of scores (low, medium, and high) for appetite and general nutrition knowledge. Cut-off points of 8 and above were used to determine risk for anxiety and depression in the HADS (Herrmann, 1997) and scores of 20 and beyond were utilized to define satisfaction with life in SWLS (Quinlivan, Ung and Petersen, 2011). Significance between proportions of under-, adequate or over-reporting according to maternal characteristics was tested using Pearson's chi square test using available data. Fisher exact test was used when a cell had an observed count of less than 5.

To assess whether nutrient intakes varied according to different categories of misreporting, mean nutrient densities (%) of total energy for macronutrients and amounts of macro- and micronutrients per 1,000 kcal) were compared between under-, adequate, and over-reporters by using ANOVA F test.

The significance level was set at 5% and all statistical analyses were performed using SPSS version 14.0 (SPSS Inc., Chicago, IL, USA). Data are presented as median (25^{th} and 75^{th} percentile) unless stated otherwise.

5.4 Results

This study included a total of 98 severely obese and 68 normal weight pregnant women. The demographic characteristics of the subjects are presented in Table 5.1. Compared to lean, obese subjects were of younger age, had higher parity and lower DEPCAT status. Overall, both obese and lean participants who were included in this study were found to be largely representative of the larger HIP cohort as there were no significant differences in the demographic characteristics between these populations (refer Appendix I).

Table 5.1

Demographic characteristics of study participants

		Obese (n=98)		Lean (n=68)		
		Mean	(Range or %)	Mean	(Range or %)	*P Value*
Age (years)		31.6	(21.5 – 43.6)	33.5	(24.1 – 42.3)	*P=0.015*‡
BMI at booking (kg/m^2)		44.8	(38.1 – 61.1)	22.7	(19.4 – 27.6)	*P<0.001*‡
Parity	Nulliparous	47	(48.0%)	45	(66.2%)	*P=0.026*†
	Multiparous	51	(52.0%)	23	(33.8%)	
Ethnicity	Caucasian	96	(98.0%)	68	(100%)	*P=0.513*†
	Non-Caucasian	2	(2.0%)			
DEPCAT status	Low (1 to 2)	15	(15.3%)	1	(1.5%)	*P<0.001*†
	Middle (3 to 5)	73	(74.5%)	46	(67.6%)	
	High (6 to 7)	10	(10.2%)	21	(30.9%)	

‡ Tested using independent t-test; † Tested using chi square test; DEPCAT – Deprivation Category

At 28 weeks gestation, reported total energy intake was similar in obese and lean (*P=NS*). Median EER was significantly higher in obese than lean (3,011 (SD) kcal/day vs 2,419 (SD) kcal/day, *P<0.001*). In contrast, median EI:EER ratio was lower in obese than lean (0.72 (SD) vs 0.95 (SD), *P<0.001*), indicating a higher degree of under-reporting in the obese group as compared to their lean counterparts. There was also a higher prevalence of under-reporting (49.0% vs 14.7%) and a lower prevalence of over-reporting (7.1% vs 13.2%) in the obese than in lean group (*P<0.001 for* both within and between groups).

Total caloric intake, EI:EER ratio, and the prevalence of reporting inaccuracy, did not vary according to maternal characteristics in obese (Tables 5.2a and 5.3a). In lean group (Table 5.2b), energy intake and EI:EER ratio significantly increased with degree of GWG adequacy. EI:EER ratio was also higher in participants who did not meet the minimal recommendations of PA. Also in lean, the prevalence of under-reporting was highest ($P=0.005$) in participants who had inadequate weight increment during pregnancy and over-reporting occurred most frequently ($P<0.001$) in those who gained weight excessively (Table 5.3b).

Prevalence of misreporting was not associated with factors that may influence dietary intake such as appetite, general nutrition knowledge, and eating behaviours, as demonstrated by the lack of association between EI:EER ratio and these scores in both obese and lean groups (Table 5.4).

Table 5.2a

Energy intake and ratio of energy intake to estimated energy requirement according to maternal characteristics (obese group)

Characteristics	n	%	Energy intake (kcal/day)[a]			EI:EER ratio		
			Median	(P_{25}, P_{75})	*P value*[b]	Median	(P_{25}, P_{75})	*P value*[b]
Total	98	100	2192	(1902, 2757)		0.72	(0.60, 0.90)	
Age (years)								
<25	7	7.1	1857	(1548, 2823)	*0.853*	0.60	(0.47, 0.99)	*0.653*
25 to <30	31	31.6	2437	(2017, 2856)		0.78	(0.63, 0.92)	
30 to <35	36	36.7	2170	(1647, 2636)		0.71	(0.54, 0.90)	
≥35	24	24.6	2070	(1830, 2328)		0.68	(0.59, 0.82)	
DEPCAT status								
1 to 3	27	27.6	2159	(1866, 2629)	*0.881*	0.74	(0.58, 0.92)	*0.854*
4 to 7	71	92.4	2215	(1748, 2656)		0.72	(0.61, 0.88)	.
Smoking in pregnancy								
No	87	88.7	2215	(1862, 5656)	*0.832*	0.72	(0.61, 0.90)	*0.869*
Yes	8	8.2	2097	(1642, 3197)		0.71	(0.48, 1.12)	
NA	*3*	*3.1*	*1645*	*(1266, 2173)*		*0.58*	*(0.44, 0.81)*	
Alcohol in pregnancy								
No	91	92.8	2173	(1794, 2663)	*0.429*	0.72	(0.60, 0.91)	*0.230*
Yes	7	7.2	2215	(1686, 2243)		0.63	(0.54, 0.78)	
Nulliparous								
No	51	52.0	2211	(1764, 2618)	*0.185*	0.72	(0.57, 0.90)	*0.274*
Yes	47	48.0	2173	(1862, 2656)		0.75	(0.61, 0.90)	
Adequacy of GWG								
Inadequate	40	40.8	2133	(1731, 2470)	*0.267*	0.68	(0.56, 0.82)	*0.417*
Adequate	35	35.7	2219	(1792, 2618)		0.77	(,0.62)0.88	
Excessive	23	23.5	2400	(1794, 3086)		0.78	(0.61, 0.96)	
Met PA guidelines								
No	44	44.9	2169	(1661, 2675)	*0.744*	0.76	(0.56, 0.91)	*0.629*
Yes	14	14.3	2137	(1924, 2520)		0.67	(0.59, 0.72)	
NA	*40*	*40.8*	*2224*	*(1881, 2649)*		*0.74*	*(0.61, 0.90)*	
Satisfaction with life								
Satisfied	69	70.4	2211	(1934, 2660)	*0.435*	0.74	(0.61, 0.90)	*0.777*
Not satisfied	21	21.4	2243	(1654, 2921)		0.63	(0.51, 0.96)	
NA	*8*	*8.2*	*1968*	*(1660, 2320)*		*0.63*	*(0.51, 0.80)*	
Anxiety								
No risk	59	60.2	2159	(1794, 2546)	*0.295*	0.69	(0.59, 0.85)	*0.337*
At risk	30	30.6	2350	(1844, 2709)		0.80	(0.61, 0.91)	
NA	*9*	*9.2*	*2173*	*(1688, 2394)*		*0.64*	*(0.54, 0.82)*	
Depression								
No risk	73	74.5	2166	(1828, 2660)	*0.663*	0.70	(0.59, 0.89)	*0.569*
At risk	17	17.3	2400	(1784, 3062)		0.78	(0.61, 0.92)	
NA	*8*	*8.2*	*1968*	*(1660, 2320)*		*0.63*	*(0.51, 0.80)*	

EER-Estimated energy requirement; EI-Energy intake, P_{25}-25[th] percentile; P_{75}-75[th] percentile; DEPCAT-Deprivation Category; GWG-Gestational weight gain; PA-Physical activity; NA-Data unavailable (not included in statistical tests)
[a] Statistical testing for energy intake & EI:EER was conducted after log-transformation
[b] Tested using analysis of variance F test or independent samples t test and only included available data

Table 5.2b

Energy intake and ratio of energy intake to estimated energy requirement according to maternal characteristics (lean group)

Characteristics	n	%	Energy intake (kcal/day)[a]			EI:EER ratio		
			Median	(P_{25}, P_{75})	*P value*[b]	Median	(P_{25}, P_{75})	*P value*[b]
Total	68	100	2318	(1785, 2636)		0.95	(0.80, 1.13)	
Age (years)								
<25	2	5.9	2342	(1540, 3143)	*0.811*	0.96	(0.55, 1.37)	*0.815*
25 to <30	7	7.1	2737	(1881, 3200)		1.08	(0.73, 1.32)	
30 to <35	33	48.5	2185	(1983, 2738)		0.93	(0.76, 1.14)	
≥35	26	38.2	2376	(1834, 2790)		0.94	(0.82, 1.10)	
DEPCAT status								
1 to 3	53	77.9	2398	(1894, 2946)	*0.359*	0.96	(0.80, 1.17)	*0.223*
4 to 7	15	22.1	2097	(1993, 2729)		0.90	(0.73, 1.08)	
Smoking in pregnancy								
No	58	85.3	2318	(1896, 2750)		0.95	(0.79, 1.11)	
Yes	0	0						
NA	*10*	*14.7*	*2314*	*(1855, 3051)*		*0.98*	*(0.77, 1.20)*	
Alcohol in pregnancy								
No	58	85.3	2215	(1686, 2243)	*0.012*	0.91	(0.74, 1.11)	*0.108*
Yes	10	14.7	2736	(2556, 3299)		1.10	(0.94, 1.20)	
Nulliparous								
No	23	33.8	2585	(1840, 2876)	*0.564*	0.99	(0.82, 1.13)	*0.383*
Yes	45	66.2	2190	(1907, 2733)		0.92	(0.76, 1.13)	
Adequacy of GWG								
Inadequate	40	58.8	2179	(1885, 2596)	*0.042*	0.93	(0.74, 1.07)	*0.048*
Adequate	21	30.9	2598	(1942, 2907)		1.08	(0.82, 1.19)	
Excessive	7	10.3	3018	(2439, 3416)		1.28	(0.93, 1.44)	
Met PA guidelines								
No	28	41.2	2504	(2100, 3112)	*0.794*	1.04	(0.88, 1.29)	*0.043*
Yes	23	33.8	2406	(1973, 2876)		0.93	(0.78, 1.08)	
NA	*17*	*25.0*	*1993*	*(1786, 2545)*		*0.82*	*(0.71, 1.08)*	
Satisfaction with life								
Satisfied	56	82.4	2188	(1902, 2742)	*0.303*	0.94	(0.80, 1.10)	*0.061*
Not satisfied	4	5.9	3084	(1909, 3905)		1.29	(0.73, 1.62)	
NA	*8*	*11.8*	*2648*	*(1875, 2744)*		*0.99*	*(0.77, 1.10)*	
Anxiety								
No risk	51	75.0	2398	(1897, 2764)	*0.460*	0.96	(0.74, 1.15)	*0.888*
At risk	9	13.2	2067	(1904, 2631)		0.90	(0.81, 1.13)	
NA	*8*	*11.8*	*2648*	*(1875, 2744)*		*0.99*	*(0.77, 1.10)*	
Depression								
No risk	57	84.8	2244	(1940, 2762)	*0.932*	0.95	(0.81, 1.14)	*0.778*
At risk	2	2.9	2483	(1816, 3150)		1.04	(0.79, 1.28)	
NA	*9*	*13.3*	*2568*	*(1466, 2742)*		*0.92*	*(0.64, 1.10)*	

EER-Estimated energy requirement; EI-Energy intake, P_{25}-25th percentile; P_{75}-75th percentile; DEPCAT- Deprivation Category; GWG-Gestational weight gain; PA-Physical activity; NA-Data unavailable (not included in statistical tests)

[a] Statistical testing for energy intake & EI:EER was conducted after log-transformation

[b] Tested using analysis of variance F test or independent samples t test and only included available data

Table 5.3a

Prevalence of low, adequate and high energy-reporting according to maternal characteristics (obese group)

Characteristics	Low Energy Reporters		Adequate Energy Reporters		High Energy Reporters		*P value*[a]
	n	%	n	%	n	%	
Total	48	49.0	43	43.9	7	7.1	<0.001
Age (years)							
<25	4	57.1	2	28.6	1	14.3	*0.231*
25 to <30	13	41.9	15	48.4	3	9.7	
30 to <35	18	50.0	16	44.4	2	5.6	
≥35	13	54.2	10	41.7	1	4.1	
DEPCAT status							
1 to 3	13	48.1	12	44.4	2	7.5	*0.878*
4 to 7	35	49.0	31	43.7	5	7.0	
Smoking in pregnancy							
No	42	48.3	39	44.8	6	6.9	*0.816*
Yes	4	50.0	3	37.5	1	12.5	
Alcohol in pregnancy							
No	44	48.3	40	44.0	7	7.7	*0.725*
Yes	4	57.1	3	42.9	0	0.0	
Nulliparous							
No	23	48.9	20	42.6	4	8.5	*0.873*
Yes	25	49.0	23	45.1	3	5.9	
Adequacy of GWG							
Inadequate	23	57.5	14	35.0	3	7.5	*0.567*
Adequate	14	40.0	19	54.3	2	5.7	
Excessive	11	47.8	10	43.5	2	8.7	
Met PA guidelines							
No	20	45.5	22	50	2	4.5	*0.061*
Yes	11	78.6	2	14.3	1	7.1	
Satisfaction with life							
Satisfied	31	44.9	33	47.8	5	7.3	*0.504*
Not satisfied	12	57.1	7	33.3	2	9.5	
Anxiety							
No risk	31	52.5	23	39.0	5	8.5	*0.435*
At risk	12	40.0	16	53.3	2	6.7	
Depression							
No risk	37	50.7	30	41.1	6	8.2	*0.416*
At risk	6	35.3	10	58.8	1	5.9	

DEPCAT - Deprivation Category; GWG-Gestational weight gain; PA-Physical activity;
NA-Data unavailable
[a] Tested using chi square test

Table 5.3b

Prevalence of low, adequate and high energy-reporting according to maternal characteristics (lean group)

Characteristics	Low Energy Reporters		Adequate Energy Reporters		High Energy Reporters		*P value*[a]
	n	%	n	%	n	%	
Total	10	14.7	49	72.1	9	13.2	<0.001
Age (years)							
<25	1	50.0	0	0.0	1	50.0	*0.612*
25 to <30	1	14.3	4	57.1	2	28.6	
30 to <35	6	18.2	23	69.7	4	12.1	
≥35	2	7.7	22	84.6	2	7.7	
DEPCAT status							
1 to 3	7	13.2	37	69.8	9	17.0	*0.275*
4 to 7	3	20.0	12	80.0	0	0.0	
Smoking in pregnancy							
No	8	13.8	43	74.1	7	12.1	*NA*
Yes	0	0.0	0	0.0	0	0.0	
Alcohol in pregnancy							
No	10	17.2	41	70.7	7	12.1	*0.328*
Yes	0	0.0	8	80.0	2	20.0	
Nulliparous							
No	8	17.8	32	71.1	5	11.1	*0.516*
Yes	2	8.7	17	73.9	4	17.4	
Adequacy of GWG							
Inadequate	7	17.5	31	77.5	2	5.0	*0.005*
Adequate	2	9.5	16	76.2	3	14.3	
Excessive	1	14.3	2	28.6	4	57.1	
Met PA guidelines							
No	2	7.1	18	64.3	8	28.6	*0.059*
Yes	4	17.4	18	78.3	1	4.3	
Satisfaction with life							
Satisfied	8	14.3	43	76.8	5	8.9	*<0.001*
Not satisfied	1	25.0	0	0.0	3	75.0	
Anxiety							
No risk	9	19.1	36	76.6	6	12.8	*0.321*
At risk	0	0.0	7	77.8	2	22.2	
Depression							
No risk	8	14.0	42	73.7	7	12.3	*0.293*
At risk	0	0.0	1	50.0	1	50.0	

DEPCAT - Deprivation Category; GWG-Gestational weight gain; PA-Physical activity;
NA-Data unavailable
[a] Tested using chi square test

Table 5.4

Pearson correlation coefficients between EI:EER ratio and scores of reported appetite, general nutrition knowledge and eating behaviours

	Obese				Lean			
	n	r	*P value*[1]	*P value*[2]	n	r	*P value*[1]	*P value*[2]
Appetite	35	-0.099	*0.571*	*0.850*	*40*	0.292	*0.068*	*0.076*
General nutrition knowledge	48	-0.072	*0.629*	*0.773*	*51*	-0.153	*0.285*	*0.174*
Restraint eating	25	-0.080	*0.704*	*0.411*	25	-0.112	*0.595*	*0.555*
Emotional eating	25	0.276	*0.182*	*0.517*	25	-0.013	*0.951*	*0.985*
Externally cued eating	25	0.415	*0.039*	*0.113*	25	0.381	*0.051*	*0.060*

EI-Energy intake***;*** EER-Estimated energy requirement
P value [1] – Unadjusted data
P value [2] – Data adjusted for age, parity, ethnicity, and DEPCAT status

A comparison of total energy intake and nutrient density (per 1,000 kcal) across categories of misreporting (Tables 5.5a and 5.5b) showed similar patterns in both obese and lean groups. As expected, total reported calories were lowest (*P<0.001*) in under-reporters, as compared to adequate and over-reporters. Percentage of protein (of total calories) was similar across categories of energy reporting. Percentage of fat was lowest (*P<0.01* in both obese and lean groups) and percentage of carbohydrate was highest in under-reporters, as compared to adequate or over-reporters (*P<0.05* in both obese and lean groups). Reported intakes of fatty acids such as saturated, mono- and polyunsaturated fatty acids (SFA, MUFA and PUFA) and dietary cholesterol increased with degree of misreporting. Total reported carbohydrate intake was highest in under-reporters, and this was comprised of proportionally higher amount of starchy, as compared to sugary foods, although this was only found to be significant in the lean group. In general, reported foods of under-reporters in both obese and lean groups contained higher proportions of dietary fibre, iron, copper, retinol, folic acid and vitamin C, than adequate or over-reporters.

Table 5.5a

Nutrient density of macro and micronutrients according to low, adequate and high energy-reporting (obese group)

Nutrient per 1,000 kcal	Low Energy Reporting (n=48)		Adequate Energy Reporting (n=43)		High Energy Reporting (n=7)		*P value*[a]
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})	
Energy (kcal/day)*	1778	(1568, 2039)	2565	(2219, 2732)	4649	(4466, 4865)	*<0.001*
Protein (% kcal)	15.9	(14.3, 18.4)	16.0	(14.7, 17.9)	14.0	(11.5, 16.0)	*0.050*
Fat (% kcal)	34.2	(32.6, 37.3)	36.6	(34.6, 39.4)	37.1	(35.3, 42.4)	*0.007*
Carbohydrate (% kcal)	48.1	(46.7, 52.2)	46.9	(43.2, 49.7)	48.0	(45.0, 51.8)	*0.032*
Protein (g)	39.9	(35.8, 46.0)	40.1	(36.8, 44.7)	35.1	(28.8, 40.1)	*0.050*
Fat (g)	38.0	(36.2, 41.4)	40.7	(38.4, 43.8)	41.2	(39.2, 47.1)	*0.007*
Carbohydrate (g)	128.4	(123.9, 139.2)	123.9	(114.9, 132.0)	126.7	(120.2, 137.5)	*0.028*
SFA (g)	15.0	(13.0, 16.6)	16.0	(14.8, 17.5)	16.2	(14.9, 17.0)	*0.005*
MUFA (g)	13.1	(11.9, 14.1)	14.0	(13.1, 15.3)	14.3	(13.2, 16.2)	*0.006*
PUFA (g)*	6.7	(6.0, 7.4)	6.4	(5.8, 7.5)	6.4	(5.9, 7.1)	*<0.001*
Cholesterol (mg)	113.1	(94.0, 129.3)	142.7	(112.5, 171.4)	89.0	(79.3, 126.3)	*0.010*
Sugars (g)	58.2	(49.0, 70.6)	57.2	(44.5, 68.0)	61.8	(55.0, 81.3)	*0.370*
Starch (g)	68.2	(61.9, 74.2)	63.1	(56.2, 70.4)	64.9	(53.4, 65.8)	*0.092*
Fibre (g)	9.0	(7.9, 11.0)	7.6	(6.5, 9.2)	7.3	(6.1, 11.3)	*0.004*
Sodium (mg)	1375	(1224, 1447)	1359	(1218, 1436)	1323	(1199, 1582)	*0.970*
Potassium (mg)	1676	(1465, 1895)	1487	(1402, 1616)	1440	(1262, 1906)	*0.034*
Calcium (mg)*	511.6	(439.5, 572.8)	487.8	(412.1, 569.4)	426.2	(353.5, 493.0)	*0.006*
Magnesium (mg)	176.7	(157.0, 196.7)	150.6	(141.0, 165.1)	154.8	(146.9, 169.0)	*<0.001*
Phosphorus (mg)	762.3	(671.3, 861.4)	741.7	(657.7, 812.1)	614.8	(583.4, 726.8)	*0.021*
Iron (mg)	6.22	(5.45, 6.99)	5.87	(5.24, 6.26)	5.08	(4.67, 6.03)	*0.015*
Copper (mg)*	1.38	(1.15, 1.72)	1.07	(0.88, 1.30)	1.40	(1.17, 1.49)	*<0.001*
Zinc (mg)	4.90	(4.35, 5.63)	5.05	(4.51, 5.48)	3.64	(3.56, 4.80)	*0.025*
Chloride (mg)	2050	(1930, 2178)	2036	(1880, 2175)	2074	(1832, 2464)	*0.921*
Manganese (mg)	1.63	(1.30, 1.96)	1.43	(1.18, 1.60)	1.29	(1.12, 1.48)	*0.004*
Selenium (µg)*	24.3	(20.5, 32.8)	24.9	(19.9, 31.1)	26.2	(17.1, 31.6)	*0.791*
Iodine (µg)	98.6	(82.4, 112.8)	100.4	(80.4, 116.4)	86.1	(68.4, 105.4)	*0.449*
Retinol (µg)	114.6	(85.6, 134.4)	147.8	(127.4, 173.6)	115.4	(106.5, 154.0)	*<0.001*
B-carotene (µg)*	1647	(1318, 2519)	1148	(932, 2002)	1243	(630, 2284)	*0.028*
Vitamin D (µg)*	1.11	(0.89, 1.83)	1.35	(1.00, 1.89)	1.08	(0.59, 1.83)	*0.097*
Vitamin E (mg)	4.38	(3.80, 5.08)	4.58	(3.98, 5.03)	4.92	(3.46, 5.90)	*0.423*
Thiamine (mg)	0.87	(0.77, 0.94)	0.78	(0.68, 0.90)	0.76	(0.74, 0.82)	*0.019*
Riboflavin (mg)	0.87	(0.70, 1.05)	0.86	(0.65, 1.04)	0.81	(0.65, 0.84)	*0.384*
Niacin (mg)	10.4	(8.7,12.3)	9.7	(8.8, 10.8)	8.7	(7.2, 11.5)	*0.168*
Potential niacin (mg)	8.5	(7.6, 9.8)	8.6	(8.0, 10.0)	7.3	(5.6, 9.2)	*0.033*
Vitamin B6 (mg)	1.16	(1.01, 1.32)	1.05	(0.92, 1.23)	1.05	(0.80, 1.21)	*0.074*
Vitamin B12 (µg)*	2.41	(1.84, 3.11)	2.79	(2.19, 3.28)	2.10	(1.17, 2.82)	*0.104*
Folic acid (µg)*	140.5	(107.1, 167.0)	115.5	(102.1, 140.4)	109.9	(83.4, 124.7)	*0.014*
Pantothenic acid (mg)	2.68	(2.26, 2.98)	2.56	(2.29, 2.88)	2.28	(2.13, 2.58)	*0.195*
Biotin (µg)	16.11	(14.1, 20.1)	16.5	(14.8, 19.5)	13.8	(12.8, 16.5)	*0.198*
Vitamin C (mg)	68.2	(46.1, 88.8)	53.3	(39.6, 72.2)	46.2	(36.1, 83.2)	*0.042*
Vitamin K (mg)*	15.2	(9.8, 34.3)	11.9	(7.4, 22.6)	12.4	(7.2, 18.2)	*0.234*
Alcohol (g)*	0.00	(0.00, 0.00)	0.0	(0.0, 0. 0)	0.0	(0.0, 0.0)	*0.187*

P_{25}-25th percentile; P_{75}-75th percentile;
SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids; PUFA – Polyunsaturated fatty acids
* Data normalized using log-transformation; [a] Tested using analysis of variance F test

Table 5.5b

Nutrient density of macro and micronutrients according to low, adequate and high energy-reporting (lean group)

Nutrient per 1,000 kcal	Low Energy Reporting (n=10)		Adequate Energy Reporting (n=49)		High Energy Reporting (n=9)		*P value*[a]
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})	
Energy (kcal/day)*	1650	(1331, 1916)	2354	(2042, 2733)	3416	(3146, 3662)	*<0.001*
Protein (% kcal)	15.6	(14.2, 17.9)	16.0	(13.9, 17.4)	15.8	(14.7, 18.0)	*0.834*
Fat (% kcal)	32.9	(30.0, 38.5)	35.4	(33.3, 39.0)	39.7	(37.2, 41.1)	*0.002*
Carbohydrate (% kcal)	50.4	(47.4, 53.8)	48.2	(44.6, 51.9)	42.9	(41.6, 47.9)	*0.038*
Protein (g)	39.1	(35.5, 44.7)	40.1	(34.8, 43.6)	39.5	(36.7, 45.1)	*0.834*
Fat (g)	36.5	(33.3, 42.8)	39.4	(37.0, 43.3)	44.2	(41.3, 45.6)	*0.020*
Carbohydrate (g)	133.9	(126.7, 143.1)	127.7	(117.0, 136.4)	114.2	(,110.8)123.0	*0.018*
SFA (g)	13.5	(10.7, 17.1)	15.7	(13.9, 16.5)	17.8	(16.4, 19.2)	*0.018*
MUFA (g)	12.8	(11.7, 14.4)	13.6	(12.3, 14.7)	14.8	(14.1, 15.2)	*0.008*
PUFA (g)*	6.7	(5.8, 7.0)	6.6	(6.0, 7.3)	6.4	(6.2, 7.4)	*<0.001*
Cholesterol (mg)	108.9	(76.1, 142.9)	110.7	(82.2, 132.0)	141.3	(110.4, 165.8)	*0.007*
Sugars (g)	60.4	(55.5, 72.7)	60.2	(48.0, 67.2)	59.1	(45.9, 67.3)	*0.418*
Starch (g)	68.1	(60.3, 77.6)	63.7	(58.2, 72.2)	56.2	(49.8, 69.4)	*0.003*
Fibre (g)	10.5	(6.7, 12.2)	9.6	(8.5, 10.8)	7.6	(7.2, 9.4)	*0.002*
Sodium (mg)	1259	(1120, 1558)	1353	(1245, 1441)	1400	(1298, 1453)	*0.039*
Potassium (mg)	1746	(1544, 1915)	1650	(1497, 1812)	1470	(1406, 1608)	*0.093*
Calcium (mg)*	493.4	(468.5, 558.2)	538.4	(497.1, 601.1)	501.3	(478.3, 660.3)	*0.817*
Magnesium (mg)	188.0	(165.8, 210.5)	181.0	(170.3, 196.1)	160.7	(55.1, 169.3)	*0.060*
Phosphorus (mg)	782.4	(690.2, 889.4)	774.9	(706.9, 825.0)	757.5	(692.3, 809.2)	*0.533*
Iron (mg)	7.68	(6.09, 8.36)	6.71	(6.05, 7.57)	5.88	(5.39, 6.64)	*0.036*
Copper (mg)*	1.10	(0.98, 1.23)	1.44	(1.22, 1.66)	1.09	(1.04, 1.51)	*0.013*
Zinc (mg)	5.32	(4.34, 5.47)	5.12	(4.56, 5.56)	4.98	(4.65, 5.85)	*0.085*
Chloride (mg)	1885	(1705, 2247)	2057	(1876, 2189)	2125	(1970, 2218)	*0.739*
Manganese (mg)	1.94	(1.36, 2.60)	1.91	(1.62, 2.22)	1.76	(1.48, 1.94)	*0.366*
Selenium (µg)*	27.2	(24.4, 34.7)	27.2	(22.6, 30.2)	23.9	(22.0, 30.2,)	*0.523*
Iodine (µg)	114.8	(99.2, 152.8)	103.9	(87.1, 122.4)	115.2	(80.4, 130.2)	*0.298*
Retinol (µg)	117.0	(89.8, 144.0)	133.8	(114.9, 163.0)	179.4	(141.1, 200.1)	*0.040*
B-carotene (µg)*	1761	(1247, 2422)	1997	(1204, 2796)	1492	(1286, 2100)	*0.648*
Vitamin D (µg)*	1.68	(0.92, 2.53)	1.52	(1.13, 2.22)	1.75	(1.25, 2.01)	*0.881*
Vitamin E (mg)	5.87	(4.98, 0.42)	4.83	(4.31, 6.07)	4.35	(3.97, 5.65)	*0.122*
Thiamine (mg)	0.87	(0.71, 0.94)	0.82	(0.75, 0.91)	0.76	(0.73, 0.84)	*0.255*
Riboflavin (mg)	1.02	(0.87, 1.25)	0.98	(0.86, 1.08)	0.93	(0.85, 1.03)	*0.360*
Niacin (mg)	9.57	(7.72, 11.7)	9.7	(8.3, 10.8)	8.59	(8.0, 10.7)	*0.873*
Potential niacin (mg)	8.7	(7.6, 9.4)	8.6	(7.7, 9.4)	8.7	(7.9, 10.8)	*0.608*
Vitamin B6 (mg)	1.14	(0.92, 1.38)	1.06	(0.93, 1.18)	0.99	(0.94, 1.06)	*0.158*
Vitamin B12 (µg)*	2.80	(2.00, 3.96)	2.77	(2.13,)	2.83	(2.10, 3.82)	*0.747*
Folic acid (µg)*	152.3	(133.4, 168.7)	148.2	(130.8, 179.1)	126.0	(120.7, 137.3)	*0.045*
Pantothenic acid (mg)	2.69	(2.47, 3.22)	2.64	(2.43, 2.94)	2.62	(2.52, 2.97)	*0.257*
Biotin (µg)	22.0	(16.1, 25.9)	19.4	(17.1, 21.4)	19.3	(17.3, 20.1)	*0.070*
Vitamin C (mg)	78.6	(47.3, 85.8)	65.8	(49.1, 85.8)	54.7	(40.2, 76.2)	*0.039*
Vitamin K (mg)*	26.5	(5.9, 32.4)	28.9	(18.3, 65.9)	27.6	(13.0, 51.9)	*0.126*
Alcohol (g)*	0.0	(0.0, 0.0)	0.0	(0.0, 0.9)	0.0	(0.1, 2.0)	*0.104*

P_{25}-25th percentile; P_{75}-75th percentile;
SFA – Saturated fatty acids; MUFA – Monounsaturated fatty acids; PUFA – Polyunsaturated fatty acids
* Data normalized using log-transformation; [a] Tested using analysis of variance F test

5.5 Discussion

The aim of this chapter was to assess the prevalence of misreporting of energy intake during late pregnancy in severely obese pregnant women compared with lean pregnant women among those who completed the SCG-FFQ for the EBIP study. It was found that under-reporting of energy intake was almost three-fold more prevalent and occurred to a higher degree in the obese group as compared to lean. In obese, this prevalence did not vary according to different maternal characteristics and was not associated with factors that may influence dietary intake such as appetite, general nutrition knowledge and eating behaviours.

FFQ has been extensively used for assessing dietary intakes in epidemiological studies due to its practicality. It is specifically designed to assess long-term and habitual diet, and has been reported to give a reliable estimate of nutrient intakes in different populations (Willet, 1998). This method was used as the main dietary assessment instrument in this study and was found to be a reasonably valid tool for ranking severely obese pregnant women according to the levels of their dietary intake when compared to dietary intake obtained from a 4-day food diary (as discussed in chapter 3). In the current study (as discussed in Chapter 4), obese women reported to be eating similar total calories as lean during pregnancy. They also reported to significantly reduce their total energy intake from early to late pregnancy. Although these obese women who attended the Antenatal Metabolic Clinic only gained half as much weight as the lean during pregnancy, there was no association observed between GWG and total energy intake in this (obese) group (as presented in Chapter 8). Since the reporting accuracy was evaluated at the same time as dietary intake in late pregnancy, the reduction in reported calories could probably be due to underreporting which was prevalent in almost half of the obese population.

Determination of measurement error in energy intake should ideally be done by using an objective estimate of energy requirement based on total energy expenditure (TEE). The DLW is considered the most ideal technique for measuring TEE but its high costs renders it unsuitable for use in large population studies. As an alternative, prediction equations such as the ones published by the IOM in 2002 as part of its Dietary Reference Intakes were used for calculation of estimated energy requirement. These EER equations were developed from an extensive DLW database for TEE measurements in adults, children and pregnant women with varying levels of PA (IOM, 2002). Even though these EER equations are specific for overweight individuals, they were constructed based on information for adult males and females with BMI ≥ 26.0. The equations may not be fully accurate for severely obese women (with BMI ≥40.0) who are also pregnant. Under-reporting was found to be more prevalent in the obese group as compared to the lean. It also occurred at a higher degree in obese as they reported energy intakes of only 72% of EER, compared to lean (95% of EER). Previous studies have demonstrated an association of excess body weight with the prevalence of under-reporting (Poslusna et al, 2009, Scagliusi et al, 2009, Ferrari et al, 2002, Hill and Davies, 2001). Although the degree of under-reporting has been shown to increase with BMI, the relation is non-linear, levelling out at a BMI > 35kg/m^2 (Tooze et al, 2004). Under-reporting has also been linked with demographic factors such as lower socioeconomic status and educational achievements (Poslusna et al, 2009, Scagliusi et al, 2009, Hill and Davies, 2001) as well as certain psychological conditions such as depression (Poslusna et al, 2009). None of these factors was linked to misreporting prevalence in our obese group. However, in the lean group, the prevalence of under- and over-reporting was lowest in respondents who were categorized as 'Satisfied with life' compared with those who were not.

Underreporting of energy intake is also prevalent in populations of pregnant women. Derbyshire et al (2006) studied 72 Caucasian, primiparous, pregnant women during early pregnancy and identified that women with a high pre-pregnancy BMI were more likely to under-report nutrient intakes. A possible explanation the author provided was that overweight or obese women may restrain or monitor their dietary intakes during pregnancy to prevent excess weight gain during pregnancy. Derbyshire et al (2006) also reported that heavier subjects tended to avoid energy-dense foods, or ate them only in small portions and also consumed more reduced-fat or 'lite' foods. This study was, however, carried out in early pregnancy (between weeks 9 and 15 of gestation) during which nausea and vomiting is commonly experienced by pregnant women, and which might have influenced the low reported food intake. Furthermore, in our population, there was a significant positive association between restraint eating behaviour scores and GWG in obese women (as presented later in Chapter 7 of this thesis), and this conforms more to the proposition that pregnancy allows restrained eaters to be more relaxed about controlling their food intake (Clark and Ogden, 1999) as discussed later in Chapter 8 of this thesis. There is also a trend for degree of under-reporting to increase with advancing gestation as suggested by a systematic review (Forsum and Lof, 2007). In the 3 studies evaluated, reported energy intake differed by -2 to +10%, -9 to -21%, and -12 to -25%, from expected energy intake in trimesters 1, 2, and 3, of pregnancy (Moore et al, 2004, Kopp-Hoolihan et al, 1999, Antal et al, 1997). However, this was speculated to be due to under-eating as some women have difficulty eating large amounts of foods during late pregnancy. There are also limited data regarding the amount of energy retained in the body or mobilized from energy stores during each trimester. A woman who deposits a large amount of fat during the first or second trimester may be able to mobilize this fat store to fulfil her energy requirements later in pregnancy, even though she may not be eating as much as she should (Forsum and Lof, 2007). Under-eating, as opposed to underreporting, would also be expected to be associated with lower GWG. In the current study, the EI:EER ratio increased with GWG in the lean group, suggesting that they were reporting what they were actually eating. This was, however, not seen in obese group.

This study showed that in both lean and obese groups, under-reporters of energy intake reported lower percentage of fat (per total caloric intake) and grams of total fats (including SFA, MUFA and PUFA) and dietary cholesterol, than adequate or over-reporters.

They also tended to report a higher percentage of carbohydrate intake. In lean, this consisted of proportionally more starchy than sugary foods. The under-reporters in both groups also demonstrated higher intakes of dietary fibre, iron, copper, retinol, folic acid and vitamin C, than adequate or over-reporters. Studies have shown that inaccuracy of reporting is specific to certain nutrients or foods. Under-reporting may be characterized by a tendency to report low intakes of foods high in fat and or simple sugars such as cakes, cookies, candies, soft drinks, butter and margarine (Lutomski et al, 2010, Livingstone and Black, 2003, Heitmann and Lissner, 1995) which are deemed as having a negative health image (Macdiarmid and Blundell, 1998). On the contrary, foods which are perceived as healthy and socially desirable such as fruits and vegetables are reported in larger amounts, represented by higher intakes of dietary fibre and vitamin C in under-reporters compared to adequate reporters (Johansson et al, 1998), a pattern also seen in our subjects. Other than food eaten, misreporting is also associated with bias in reporting meal patterns. Snack foods are particularly susceptible to under-reporting, due to the perceived negative link of eating more than the necessary three meals a day (Macdiarmid and Blundell, 1998) and the unhealthy content of the foods consumed e.g. high in refined sugar (Drummond et al, 1998). Accuracy of reporting of snack foods may be influenced by the dietary assessment used. Snacking may be considered a secondary activity to eating meals so when snack foods are omitted from food records, it is either because they are forgotten when recalling intake in FFQ or 24-hour food recall (Poppit et al, 1998) or they are viewed as too much of a hassle to record in food diaries.

One of the consequences of under-reporting is bias in estimating nutrient intake. Validation of dietary intake against energy expenditure identifies only inaccuracy in reporting of total energy intake. It is essential to determine if misreporting is due to underreporting of diet as a whole (in which case the micronutrient densities per 1,000 kcal is not different between under and adequate or over- reporters) or if it involves bias in estimating nutrient intakes through selective recording of foods or altered food choices

(Livingstone and Black, 2003). There is evidence for the latter in the current study as shown by the significantly lower intake of fats and dietary cholesterol and higher contents of certain micronutrients such as dietary fibre, vitamin C, folic acid and iron in diets of under-reporters. Therefore, misreporting of total energy intake in this study was also associated with variable bias in reporting intakes of nutrients, and it was found to occur more in obese than lean groups. This may become an issue in interpretation of dietary intake findings of this group of women. It has been suggested that statistical adjustment of energy on nutrient intakes should be carried out to decrease the influence of misreporting (Poslusna et al, 2009). One such method is the residual method (which was used in the current study) where linear regression is used with total energy intake as the independent variable and intake of nutrient as dependent variable. Energy-adjusted nutrient intake is calculated by adding the residual (the difference between the observed nutrient values for each subject and the values predicted by regression equation) to the nutrient intake that corresponds with the mean total energy intake of the study population (Willet and Stampfer, 1986). This technique reduces the possible effect of measurement error caused by mis-reporting of total energy intake by producing amounts of nutrients which are independent of total energy (Poslusna et al, 2009). In Chapter 4, it was shown that this adjustment has caused the statistical difference between nutrients during early and late pregnancy in obese group (refer Tables 4.2a and 4.2c) to be no longer significant. In contrast, intakes of certain nutrients such as calcium, magnesium, beta-carotene, vitamins D and E, were found to be significantly lower between obese and lean, only after adjustment of these nutrients for total energy intake was done (Table 4.2e).

In conclusion, there was a higher prevalence, as well as a greater degree of energy under-reporting in severely obese pregnant women compared to the lean controls, confirming what others have previously reported in subjects who are obese, pregnant or female. Reporting food intake is a complex process which is influenced by one's cognitive ability, as well as certain psychological factors. The cognitive processes of recalling, estimating portion size, and computing frequency of intakes, are determined by psychological outcomes of perception, learning and reasoning (Blundell, 2000). The act of recording itself is governed by psychological factors such as the motivation to follow instructions to record things as accurately as possible, or to let the emotional and moral feelings influence it and report what is socially desirable (Blundell, 2000). The reasons for misreporting are clearly complex, very individualized, and not well understood. The characteristics of this study population of being female, obese, and pregnant, three traits which individually in population studies are associated with not reporting true dietary intakes, simply add to this conundrum. Reporting inaccuracy confounds the ability to determine habitual diets in severely obese pregnant women. Its prevalence should therefore be taken into account in assessments of possible associations between dietary intake and pregnancy outcomes in this population.

CHAPTER 6

Assessment of physical activity and validation of self-reported information using accelerometry

Chapter 6

6.1 Introduction

Physical activity (PA) during pregnancy has been widely demonstrated to have various positive effects on women's health (Weissgerber et al, 2006). PA is promoted as part of a healthy lifestyle during pregnancy, not only for its role in gestational weight management, but also to improve pregnancy outcomes for both mother and baby. Increased PA may help in preventing excess weight gain during pregnancy (Mottola et al, 2010), and women who are physically active during pregnancy may have reduced risks of developing complications such as gestational diabetes mellitus (Dye et al, 1997) and preeclampsia (Evenson et al, 2002). There is a consensus that light and moderate activities may be considered to be protective factors for foetal outcomes such as low birth weight and prematurity (Schlussel et al, 2008).

In light of these health benefits, the American College of Obstetricians and Gynaecologists and the American Heart Association recommended that in the absence of either medical or obstetric complications, pregnant women should be encouraged to adopt similar PA guidelines as recommended to their non-pregnant peers, of 30 minutes of at least moderate intensity activities for most, if not all, days of the week (Zavorsky and Longo, 2011, Artal and Toole, 2003). In a more recent update, it was recommended that all healthy adults, including pregnant women who were active prior to pregnancy, should achieve a total duration of 150 minutes of moderate intensity PA every week (Physical Activity Guidelines for Americans, U.S Department of Health and Human Services, 2008).

Despite these recommendations, PA amongst severely obese pregnant women has not been well described, even though they are the individuals who would potentially benefit the most from lifestyle interventions due to the high risks associated with obesity in pregnancy.

6.2 Hypothesis and aims

The hypothesis of this chapter was that severely obese women would do less total PA than lean women throughout pregnancy.

The aims of this chapter were to:

a) assess PA energy expenditure by using Pregnancy Physical Activity Questionnaire (PPAQ)

b) validate self-reported information from PPAQ by comparing it to data obtained from quantitative assessment using accelerometry

in obese and lean pregnant women who attended the Antenatal Metabolic Clinic.

6.3 Methods

6.3.1 Study design

This was a case-control study assessing the difference between PA levels in severely obese and lean pregnant women using PPAQ. PA was also assessed objectively using accelerometry to validate the use of PPAQ in severely obese pregnancy.

6.3.2 Ethical approval

The study was approved by the Lothian NHS Research Ethics Committee and all subjects gave written informed consent.

6.3.3 Subjects recruitment

Participants for the Energy Balance in Pregnancy (EBIP) Study were recruited among the volunteers of the Hormones and Inflammation in Pregnancy (HIP) study at the Antenatal Metabolic Clinic from August 2008 until May 2011 (for details refer section 2.1.4).

The PPAQ was given out routinely by a research midwife to all women. This was done twice during pregnancy; early (during the first visit to the clinic, between 12-20 weeks gestation) and late pregnancy (between 28-32 weeks gestation). The women were also approached personally to ask if they would like to take part in other components of EBIP study e.g. wearing accelerometer for three days.

6.3.4 Pregnancy Physical Activity Questionnaire

The PPAQ was developed to measure the duration, frequency, and intensity of total activity during pregnancy (Chasan-Taber et al, 2004) as detailed in Section 2.6.1.

6.3.5 Accelerometry

Accelerometry is a method of objectively measuring human movements by using a body-fixed device with sensor (accelerometer). The *Actical* accelerometer (Mini Mitter Company, Inc., USA) used in this study has been previously validated for use in healthy adult populations (Crouter et al, 2010, Heil, 2006). It was worn for a 3-day period (2 weekdays and 1 weekend day) except during bathing or doing water sports activities (as detailed in Section 2.6.2). In adults, 3 to 5 days of monitoring by accelerometer is usually sufficient to provide a reliable estimate of PA (Trost, McIver, and Pate, 2005).

6.3.6 Data analysis

The PPAQ were analyzed manually, following instructions provided by the main developer of the questionnaire (Chasan-Taber, 2004). The duration of time spent doing each activity was multiplied by its intensity to arrive at a measure of average weekly energy expenditure (MET-hours per week) for each activity (as detailed in Section 2.7.5).

Participants were assessed if they were meeting the PA recommendations by the American College of Sports Medicine and the American Heart Association for pregnant women without medical or obstetric complications for optimal health benefits during pregnancy (Zavorsky and Longo, 2011). This was determined using self-reported sports/exercise activity expenditure (MET-hours/week) during early and late pregnancy. Participants were categorized using cut-off values of the minimum (16 MET-hours/week) and preferable (28MET-hours/week) recommended amounts of PA energy expenditure.

The accelerometry data were retrieved by using the hardware 'Actireader' (as detailed in Section 2.7.6). A valid day of measurement was defined as one in which ≥ 500 minutes were recorded in a 24-hour period (Chasan-Taber et al, 2004).

6.3.7 Statistical Analysis

Normal distribution of data was assessed visually using Q-Q plots and histograms, and by using Kolmogorov-Smirnov test. The PPAQ data were not normally distributed and were normalized by using natural log-transformation before analysis.

Comparisons between obese and lean groups, and between early and late pregnancy were analysed by using independent t-test. Comparisons between early and late pregnancy in subjects with paired data available in each group were analysed by using paired t-test. Correlations were assessed using Pearson correlation coefficients. Intra-class correlation coefficients (ICC) were used to describe test-retest reliability of the PPAQ.

Except for paired data, all other results were adjusted for potential confounding factors such as age, parity, ethnic origin, Deprivation Category (DEPCAT) status, occupational status, and gestational duration using linear regression analysis.

The significance level was set at 5% and all statistical analyses were performed using SPSS version 14.0 (SPSS Inc., Chicago, IL, USA). Data for PPAQ were presented as median (25^{th}, 75^{th} percentiles) and data for accelerometry were presented as mean (standard error mean), unless stated otherwise.

6.4 Results

6.4.1 Pregnancy Physical Activity Questionnaire

133 obese and 81 lean completed the PPAQ during early pregnancy and 96 obese and 51 lean did this during late pregnancy. Three questionnaires from the obese-early pregnancy group had to be disregarded due to incompletion. Paired data for early and late pregnancy were available for 72 pairs from the obese group and 49 pairs from the lean group. The participants' demographic characteristics are presented in Table 6.1. Compared to lean, obese subjects were younger, had higher parity and lower DEPCAT status (Table 6.1). A higher proportion of lean subjects were working during both early and pregnancy as compared to obese. Overall, the demographic characteristics such as age, BMI at booking, parity, and ethnicity, were not significantly different between the study participants who did or did not take part in this physical activity assessment (refer Appendix J). However, a higher percentage of the participants who did not fill in the PPAQ were of low and high DEPCAT status compared to those who did (*P=0.011*).

Table 6.1

Demographic characteristics of all study participants who completed the PPAQ

		Obese (n=156)		Lean (n=84)		
		Mean	(Range or %)	Mean	(Range or %)	*P value*
Age (years)		31.5	(19.8 – 44.5)	33.7	(18.2 – 43.0)	*P=0.001*‡
BMI at booking (kg/m^2)		44.0	(37.9 – 61.1)	22.6	(19.4 – 27.6)	*P<0.001*‡
Parity	Nulliparous	73	(47.7%)	52	(63.8%)	*P=0.025*†
	Multiparous	80	(52.3%)	32	(36.2%)	
Ethnicity	Caucasian	150	(96.2%)	84	(100%)	*P=0.073*†
	Non-Caucasian	6	(3.8%)			
DEPCAT status	Low	22	(14.1%)	1	(1.2%)	*P<0.001*†
	Middle	122	(78.2%)	58	(69.0%)	
	High	12	(7.7%)	25	(29.8%)	
Working (Early pregnancy)	Yes	96	(73.3%)	75	(90.4%)	*P=0.003*†
	No	35	(26.7%)	8	(9.6%)	
Working (Late pregnancy)	Yes	71	(74.7%)	44	(86.3%)	*P=0.138* †
	No	24	(25.3%)	7	(13.7%)	

PPAQ – Pregnancy physical activity questionnaire; DEPCAT – Deprivation Category
‡ Tested using independent t-test; † Tested using chi square test

Self-reported total activity and activities classified according to activity intensity and type were not significantly different between early and late pregnancy in both obese and lean groups (Tables 6.2a and 6.2b). Changes in PA throughout pregnancy were also assessed in women with data for both early and late pregnancy (Tables 6.3a and 6.3b). Reported total PA energy expenditure was maintained in both groups although sports/exercise and vigorous activities were significantly reduced in obese and lean groups from early to late pregnancy.

Table 6.2a

Median (interquartile range) for self-reported PPAQ (MET-hours/day) by activity intensity and type (obese group)

Activity (MET-hours/day)	Early Pregnancy (n=131)		Late Pregnancy (n=95)			
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})	*P value[1]*	*P value[2]*
Total activity	24.1	(15.0, 36.5)	23.5	(15.3, 34.5)	*0.731*	*0.513*
By intensity:						
Sedentary activity	10.0	(5.5, 14.2)	11.6	(6.8, 13.9)	*0.243*	*0.222*
Light activity	14.2	(8.2, 19.5)	13.1	(8.4, 20.2)	*0.983*	*0.753*
Moderate activity	9.6	(4.6, 17.5)	8.7	(4.8, 14.4)	*0.792*	*0.961*
Vigorous activity	0.0	(0.0, 0.2)	0.0	(0.0, 0.2)	*0.686*	*0.565*
By type:						
Household/caregiving activity	11.5	(5.6, 20.8)	10.9	(5.9, 20.0)	*0.617*	*0.382*
Occupational activity	10.2	(0.0, 14.9)	11.0	(6.3, 15.6)	*0.556*	*0.342*
Sports/exercise activity	1.1	(0.3, 2.1)	0.7	(0.2, 2.0)	*0.115*	*0.154*

PPAQ – Pregnancy physical activity questionnaire; P_{25} – 25^{th} percentile, P_{75} – 75^{th} percentile
P value[1] – Independent samples t-test on log-transformed data.
P value[2] – Adjusted for age, parity, ethnicity, DEPCAT status, working status and duration of gestation

Table 6.2b

Median (interquartile range) for self-reported PPAQ (MET-hours/day) by activity intensity and type (lean group)

Activity (MET-hours/day)	Early Pregnancy (n=83)		Late Pregnancy (n=52)			
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})	*P value[1]*	*P value[2]*
Total activity	17.8	(12.0, 30.0)	19.6	(13.2, 29.0)	*0.898*	*0.798*
By intensity:						
Sedentary activity	12.2	(7.1, 14.3)	11.6	(7.3, 14.0)	*0.852*	*0.861*
Light activity	9.4	(5.6, 15.4)	10.2	(6.7, 15.4)	*0.997*	*0.969*
Moderate activity	8.4	(4.9, 14.4)	8.8	(4.5, 15.4)	*0.604*	*0.502*
Vigorous activity	0.2	(0.0, 0.9)	0.2	(0.0, 0.5)	*0.404*	*0.186*
By type:						
Household/caregiving activity	6.3	(4.3, 15.6)	7.3	(3.3, 16.0)	*0.531*	*0.258*
Occupational activity	10.8	(9.3, 12.4)	11.0	(9.3, 14.1)	*0.677*	*0.519*
Sports/exercise activity	2.0	(0.9, 3.6)	1.8	(0.8, 3.9)	*0.570*	*0.529*

PPAQ – Pregnancy physical activity questionnaire; P_{25} – 25^{th} percentile, P_{75} – 75^{th} percentile
P value[1] – Independent samples t-test on log-transformed data.
P value[2] – Adjusted for age, parity, ethnicity, DEPCAT status, working status and duration of gestation

Table 6.3a
Median (interquartile range) for self-reported PPAQ (MET-hours/day) by activity intensity and type for paired data (obese group, n=72)

Activity (MET-hours/day)	Early Pregnancy		Late Pregnancy		*P value*
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})	
Total activity	23.1	(14.7, 37.4)	23.2	(14.7, 34.1	0.399
By intensity:					
Sedentary activity	10.8	(5.9, 14.8)	10.7	(6.7, 13.8)	0.323
Light activity	13.0	(7.6, 19.4)	12.1	(7.8, 20.3)	0.851
Moderate activity	9.8	(4.8, 17.6)	8.6	(4.6, 14.1)	0.737
Vigorous activity	0.0	(0.0, 0.2)	0.0	(0.0, 0.2)	0.127
By type:					
Household/caregiving activity	11.1	(6.2, 20.6)	10.8	(5.6, 19.2)	0.556
Occupational activity	10.2	(2.1, 14.8)	11.0	(5.6, 16.1)	0.692
Sports/exercise activity	1.0	(0.3, 2.3)	0.7	(0.1, 2.2)	0.013

PPAQ – Pregnancy physical activity questionnaire; P_{25} – 25th percentile, P_{75} – 75th percentile;
P value – paired samples t-test on log-transformed data.

Table 6.3b
Median (interquartile range) for self-reported PPAQ (MET-hours/day) by activity intensity and type for paired data (lean group, n=49)

Activity (MET-hours/day)	Early Pregnancy		Late Pregnancy		*P value*
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})	
Total activity	18.1	(14.4, 34.8)	22.7	(14.6, 30.6)	*0.357*
By intensity:					
Sedentary activity	11.5	(8.0, 14.8)	11.5	(7.2, 13.9)	*0.089*
Light activity	10.1	(6.3, 16.2)	10.4	(7.7, 16.4)	*0.424*
Moderate activity	9.6	(4.7, 16.8)	9.1	(4.0, 16.3)	*0.161*
Vigorous activity	0.2	(0.0, 1.1)	0.2	(0.0, 0.4)	*0.037*
By type:					
Household/caregiving activity	6.3	(4.5, 21.2)	7.4	(3.4, 16.8)	*0.122*
Occupational activity	11.0	(9.6, 13.2)	11.6	(9.7, 14.4)	*0.863*
Sports/exercise activity	2.1	(1.0, 3.5)	1.8	(0.6, 4.0)	*0.861*

PPAQ – Pregnancy physical activity questionnaire; P_{25} – 25th percentile, P_{75} – 75th percentile;
P value – paired samples t-test on log-transformed data.

Comparing obese and lean, reported total activity was higher in obese than lean in early pregnancy but this was no longer significant after adjusting for confounding factors (Figure 6.1). There was also a trend for higher reported total activity in the obese than lean during late pregnancy but this did not reach significance. The obese group reported higher light-intensity and household/caregiving activities than lean throughout pregnancy, but these findings were no longer significant after adjustment for confounders (Tables 6.4a and 6.4b). Vigorous intensity, as well as sports/exercise activities were reported to be significantly lower in obese as compared to lean during both early and late pregnancy before and after adjustment for confounding factors.

Figure 6.1

Comparison of reported total activity energy expenditure (MET-hours/day) within and between obese and lean groups, during early and late pregnancy.

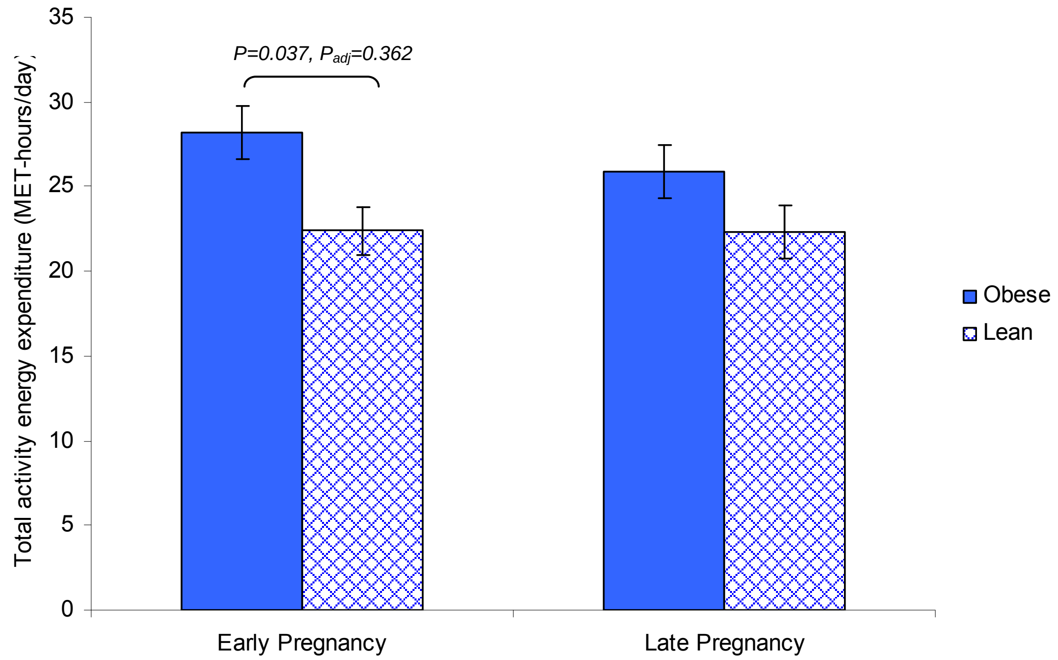


Table 6.4a
Median (interquartile range) for self-reported PPAQ (MET-hours/day) by activity intensity and type (early pregnancy)

Activity (MET-hours/day)	Obese (n=131)		Lean (n=83)			
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})	*P value[1]*	*P value[2]*
Total activity	24.1	(15.0, 36.5)	17.8	(12.0, 30.0)	*0.037*	*0.362*
By intensity:						
Sedentary activity	10.0	(5.5, 14.2)	12.2	(7.1, 14.3)	*0.241*	*0.537*
Light activity	14.2	(8.2, 19.5)	9.4	(5.6, 15.4)	*0.001*	*0.775*
Moderate activity	9.6	(4.6, 17.5)	8.4	(4.9, 14.4)	*0.785*	*0.470*
Vigorous activity	0.0	(0.0, 0.2)	0.2	(0.0, 0.9)	*<0.001*	*0.010*
By type:						
Household/caregiving activity	11.5	(5.6, 20.8)	6.3	(4.3, 15.6)	*0.002*	*0.217*
Occupational activity	10.2	(0.0, 14.9)	10.8	(9.3, 12.4)	*0.212*	*0.275*
Sports/exercise activity	1.1	(0.3, 2.1)	2.0	(0.9, 3.6)	*0.005*	*0.037*

PPAQ – Pregnancy physical activity questionnaire; P_{25} – 25th percentile, P_{75} – 75th percentile
P value[1] – Independent samples t-test on log-transformed data.
P value[2] – Adjusted for age, parity, ethnicity, DEPCAT status, working status and duration of gestation

Table 6.4b
Median (interquartile range) for self-reported PPAQ (MET-hours/day) by activity intensity and type (late pregnancy)

Activity (MET-hours/day)	Obese (n=95)		Lean (n=52)			
	Median	(P_{25}, P_{75})	Median	(P_{25}, P_{75})	*P value[1]*	*P value[2]*
Total activity	23.5	(15.3, 34.5)	19.6	(13.2, 29.0)	*0.119*	*0.667*
By intensity:						
Sedentary activity	11.6	(6.8, 13.9)	11.6	(7.3, 14.0)	*0.903*	*0.238*
Light activity	13.1	(8.4, 20.2)	10.2	(6.7, 15.4)	*0.003*	*0.528*
Moderate activity	8.7	(4.8, 14.4)	8.8	(4.5, 15.4)	*0.663*	*0.404*
Vigorous activity	0.0	(0.0, 0.2)	0.2	(0.0, 0.5)	*0.001*	*0.007*
By type:						
Household/caregiving activity	10.9	(5.9, 20.0)	7.3	(3.3, 16.0)	*0.003*	*0.178*
Occupational activity	11.0	(6.3, 15.6)	11.0	(9.3, 14.1)	*0.240*	*0.963*
Sports/exercise activity	0.7	(0.2, 2.0)	1.8	(0.8, 3.9)	*<0.001*	*0.014*

PPAQ – Pregnancy physical activity questionnaire; P_{25} – 25th percentile, P_{75} – 75th percentile
P value[1] – Independent samples t-test on log-transformed data.
P value[2] – Adjusted for age, parity, ethnicity, DEPCAT status, working status and duration of gestation

Table 6.5 showed that compared to lean, there was a significantly larger number of obese women did not meet the guidelines for PA during pregnancy as recommended by the American College of Sports Medicine and the American Heart Association (Zavorsky and Longo, 2011), based on the reported sports/exercise activities, both during early and late pregnancy. On the other hand, a greater number of lean women significantly met the minimum (16 MET-hours/week) and preferable (28 MET-hours/week) recommendations as compared to the obese group throughout pregnancy.

Table 6.5

Number (and %) of study participants who met physical activity recommendations for pregnant women by the American College of Sports Medicine and the American Heart Association

	Below recommendation		Minimum recommendation (16 MET-hours/week)		Preferable recommendation (28 MET-hours/week)		
	n	%	n	%	n	%	*P value*†
Early pregnancy:							
Obese	101	75.9	24	18.0	8	6.1	0.004
Lean	27	54.0	11	22.0	12	24.0	
Late pregnancy:							
Obese	74	76.3	17	17.5	6	6.2	0.006
Lean	47	69.2	19	23.3	15	18.5	

† tested using chi square test

6.4.2 Accelerometry

In total, 75 women (42 obese and 35 lean) were approached for the accelerometry study. Out of these, 11 obese and 4 lean women declined. 31 from each of the obese and lean group (74% and 88% respectively) agreed to take part. 1 (obese) woman changed her mind about participating, 2 women (1 obese and 1 lean) were not contactable after initially agreeing, and 2 women were excluded from the final analysis due to failure to complete the study (this comprised of 1 obese woman who only wore the accelerometer for only 1 day and 1 lean woman who wore the accelerometer for <500 minutes/day). Data were available for 28 women from each group (14 each in early and late pregnancy). Their demographic characteristics are presented in Table 6.6 which showed that obese women were of lower DEPCAT status than lean. In addition, a significantly higher proportion of lean subjects were working during both early and pregnancy as compared to obese. There was, however, no significant difference between the demographic characteristics of both obese and lean groups who did or did not take part in this objective assessment of PA (refer Appendix K). Three of the participants (2 obese, 1 lean) only had 2 valid days of measurement (1 weekday + 1 weekend day).

Table 6.6
Demographic characteristics of all study participants who completed the accelerometry study

		Obese (n=28)		Lean (n=28)		
		Mean	(Range or %)	Mean	(Range or %)	*P Value*
Age (years)		33.3	(21.0 – 43.6)	33.3	(21.1 – 42.3)	*P=0.986*‡
BMI at booking (kg/m^2)		43.6	(38.1 – 50.2)	23.2	(20.2 – 27.6)	*P<0.001*‡
Parity	Nulliparous	12	(42.9%)	16	(57.1%)	*P=0.285*†
	Multiparous	16	(57.1%)	12	(42.9%)	
Ethnicity	Caucasian	26	(92.8%)	28	(100%)	*P=0.138*†
	Non-Caucasian	2	(7.2%)			
DEPCAT status	Low	4	(14.3%)			*P=0.001*†
	Middle	23	(82.1%)	17	(60.7%)	
	High	1	(3.6%)	11	(39.3%)	
Working (Early pregnancy)	Yes	9	(64.3%)	14	(100%)	*P=0.014* †
	No	5	(35.7%)			
Working (Late pregnancy)	Yes	7	(50.0%)	26	(92.9%)	*P=0.002*†
	No	7	(50.0%)	2	(7.1%)	

‡ Tested using independent t-test; † Tested using chi square test; DEPCAT – Deprivation Category

There were no significant differences in any of the accelerometry activity counts between early and late pregnancy, either in obese or lean (Tables 6.7a and 6.7b). Obese women recorded significantly higher PA energy expenditure (adjusted for kilograms of fat-free mass) for light activity both during early and late pregnancy (Tables 6.8a and 6.8b) compared with lean. Obese women had lower average activity counts/min than lean throughout pregnancy but these findings were no longer significant after adjusting for confounders. Other accelerometry measures including total steps, PA energy expenditure for moderate and vigorous activities, and duration spent for each activity, were not significantly different between the two groups.

Table 6.7a

Mean (standard error mean, SEM) for accelerometry counts (obese)

Activity measures	Early Pregnancy (n=14)		Late Pregnancy (n=14)			
	Mean	SEM	Mean	SEM	*P value*[1]	*P value*[2]
Total steps (steps/day)	10,634	1,285	10,895	1,414	0.892	0.734
Average AC (count/min/day)	187	15	185	18	0.952	0.924
Total AEE	20.4	1.4	20.9	1.5	0.800	0.095
Light AEE	13.1	0.5	13.8	0.6	0.401	0.783
Moderate AEE	7.2	1.0	7.2	1.2	0.992	0.914
Vigorous AEE	0.01	0.00	0.0	0.0	0.157	0.235
Duration of sedentary‡	799	27	774	33	0.563	0.552
Duration of light‡	542	18	571	28	0.401	0.525
Duration of moderate‡	98	13	95	15	0.867	0.899
Duration of vigorous‡	0.05	0.03	0.0	0.0	0.153	0.274

AEE – Activity energy expenditure (kcal/kg fat-free mass/day)
‡ minutes/day
P value[1] – Independent samples t-test on log-transformed data.
P value[2] – Adjusted for age, parity, ethnicity, DEPCAT status, working status and duration of gestation

Table 6.7b

Mean (standard error mean, SEM) for accelerometry counts (lean)

Activity measures	Early Pregnancy (n=14)		Late Pregnancy (n=14)			
	Mean	SEM	Mean	SEM	*P value*[1]	*P value*[2]
Total steps (steps/day)	13,094	1,263	12,868	1,395	*0.905*	*0.788*
Average AC (count/min/day)	255	23	248	18	*0.804*	*0.638*
Total AEE	17.5	1.1	18.6	0.9	*0.440*	*0.560*
Light AEE	9.5	0.4	10.4	0.4	*0.113*	*0.589*
Moderate AEE	7.8	0.8	8.0	0.8	*0.876*	*0.377*
Vigorous AEE	0.21	0.17	0.14	0.08	*0.747*	*0.914*
Duration of sedentary‡	762	28	741	24	*0.561*	*0.761*
Duration of light‡	541	20	562	21	*0.482*	*0.346*
Duration of moderate‡	135	14	136	14	*0.941*	*0.461*
Duration of vigorous‡	1.2	0.9	0.9	0.5	*0.813*	*0.837*

AEE – Activity energy expenditure (kcal/kg fat-free mass/day)
‡ minutes/day
P value[1] – Independent samples t-test on log-transformed data.
P value[2] – Adjusted for age, parity, ethnicity, DEPCAT status, working status and duration of gestation

Table 6.8a
Mean (standard error mean, SEM) for accelerometry counts (early pregnancy)

Activity measures	Obese (n=14)		Lean (n=14)			
	Mean	SEM	Mean	SEM	*P value*[1]	*P value*[2]
Total steps (steps/day)	10,634	1,285	13,094	1,263	*0.184*	*0.445*
Average AC (count/min/day)	187	15	255	23	*0.020*	*0.623*
Total AEE	20.4	1.4	17.5	1.1	*0.109*	*0.111*
Light AEE	13.1	0.5	9.5	0.4	*<0.001*	*<0.001*
Moderate AEE	7.2	1.0	7.8	0.8	*0.634*	*0.287*
Vigorous AEE	0.01	0.00	0.21	0.17	*0.250*	*0.362*
Duration of sedentary‡	799	27	762	28	*0.353*	*0.514*
Duration of light‡	542	18	541	20	*0.960*	*0.364*
Duration of moderate‡	98	13	135	14	*0.064*	*0.971*
Duration of vigorous‡	0.05	0.03	1.2	0.9	*0.234*	*0.357*

AEE – Activity energy expenditure (kcal/kg fat-free mass/day)
‡ minutes/day
P value[1] – Independent samples t-test on log-transformed data.
P value[2] – Adjusted for age, parity, ethnicity, DEPCAT status, working status and duration of gestation

Table 6.8b
Mean (standard error mean, SEM) for accelerometry counts (late pregnancy)

Activity measures	Obese (n=14)		Lean (n=14)			
	Mean	SEM	Mean	SEM	*P value*[1]	*P value*[2]
Total steps (steps/day)	10,895	1,414	12,868	1,395	*0.330*	*0.730*
Average AC (count/min/day)	185	18	248	18	*0.019*	*0.637*
Total AEE	20.9	1.5	18.6	0.9	*0.212*	*0.160*
Light AEE	13.8	0.6	10.4	0.4	*<0.001*	*0.004*
Moderate AEE	7.2	1.2	8.0	0.8	*0.579*	*0.496*
Vigorous AEE	0.0	0.0	0.14	0.08	*0.083*	*0.910*
Duration of sedentary‡	774	33	741	24	*0.423*	*0.902*
Duration of light‡	571	28	562	21	*0.795*	*0.990*
Duration of moderate‡	95	15	136	14	*0.053*	*0.813*
Duration of vigorous‡	0.0	0.0	0.9	0.5	*0.088*	*0.934*

AEE – Activity energy expenditure (kcal/kg fat-free mass/day)
‡ minutes/day
P value[1] – Independent samples t-test on log-transformed data.
P value[2] – Adjusted for age, parity, ethnicity, DEPCAT status, working status and duration of gestation

6.4.3 Measures of reliability and validity

The test-retest reliability of PPAQ was measured using the ICC tested on log-transformed data (Table 6.9). Generally, the reproducibility between two administrations of the questionnaire was strong in both groups with an average ICC of 0.748 in obese and 0.841 in lean group. In the obese group, almost perfect agreement (>0.80) was found in household/caregiving, occupational and sport/exercise activities with lowest reproducibility for vigorous activity (0.462). Almost all activities had reproducibility > 0.80 in the lean group, except for sports and exercise (0.796) and vigorous activity (0.660).

Table 6.10 demonstrates the Pearson correlation coefficients between each activity as reported in PPAQ and accelerometry counts (average counts/min), for obese and lean groups. In obese there were no significant correlations between total activity counts/day and any activity measure. In contrast in the lean group there was a significantly inverse association between total activity counts/day and reported sedentary activity.

Table 6.9
Intraclass correlation coefficients* (ICC) between two self-administered PPAQ among obese and lean pregnant women

Reported activity (MET-hours/day)	Obese (n=58)		Lean (n=37)	
	ICC	(95% CI)	ICC	(95% CI)
Total activity	0.735	(0.552, 0.843)	0.894	(0.794, 0.945)
By intensity:				
Sedentary activity	0.789	(0.644, 0.875)	0.898	(0.801, 0.947)
Light activity	0.749	(0.575, 0.851)	0.924	(0.853, 0.961)
Moderate activity	0.712	(0.513, 0.830)	0.856	(0.720, 0.926)
Vigorous activity	0.462	(0.091, 0.682)	0.660	(0.339, 0.825)
By type:				
Household/caregiving activity	0.855	(0.754, 0.914)	0.940	(0.883, 0.969)
Occupational activity	0.863	(0.769, 0.919)	0.810	(0.631, 0.902)
Sports/exercise activity	0.816	(0.689, 0.891)	0.796	(0.506, 0.969)

* ICCs were calculated on log-transformed data

Table 6.10
Pearson correlation coefficients *(r)* between PPAQ and accelerometric total activity counts (counts/day)

Reported activity (MET-hours/day)	Obese (n=27)			Lean (n=26)		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
Total activity	0.142	*0.478*	*0.896*	0.248	*0.222*	*0.068*
By intensity:						
Sedentary activity	0.378	*0.052*	*0.841*	-0.585	*0.002*	*0.005*
Light activity	0.182	*0.364*	*0.618*	0.140	*0.495*	*0.081*
Moderate activity	0.076	*0.706*	*0.867*	0.271	*0.180*	*0.109*
Vigorous activity	0.061	*0.763*	*0.937*	0.157	*0.443*	*0.563*
By type:						
Household/caregiving activity	0.071	*0.723*	*0.471*	-0.021	*0.920*	*0.622*
Occupational activity	0.257	*0.196*	*0.929*	0.225	*0.269*	*0.435*
Sports/exercise activity	0.027	*0.894*	*0.880*	0.069	*0.739*	*0.690*

P value[1] – Correlation coefficients on log-transformed data.
P value[2] – Adjusted for age, parity, ethnicity, DEPCAT status, working status and duration of gestation

In obese, there were no significant associations between reported total activity and objectively measured total steps, activity counts/minute or activity energy expenditure (Table 6.11a) whereas in lean, reported total activity was significantly associated with total steps per day. There were no significant correlations between reported total activity and duration of sedentary, light, moderate or vigorous activities in both groups. As shown in Table 6.11b, reported sedentary activity was found to be inversely associated with total steps and positively associated with duration of sedentary activity in the lean group, although the significance levels were not maintained after adjustment for confounding factors. Reported sedentary activity was also significantly associated with total activity counts/day, total PA energy expenditure, as well as duration of moderate and vigorous activities in lean. In contrast, in obese, increased reported sedentary was associated with higher total PA energy expenditure, total activity counts/day, and duration in light activity, and with lower duration in sedentary activity, although these were no longer significant after adjusting for confounding factors. These contrasting associations between obese and lean groups are illustrated in Figures 6.1a – 6.3b.

Table 6.11a
Pearson correlation coefficients *(r)* between reported total activity energy expenditure from PPAQ and accelerometry measures

Accelerometry measures	Reported total activity (MET-hours/day)					
	Obese (n=27)			Lean (n=26)		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
Total steps (steps/day)	0.084	*0.677*	*0.743*	0.470	*0.015*	*0.011*
Total activity count (counts/day)	0.142	*0.478*	*0.896*	0.248	*0.222*	*0.068*
Total AEE	0.072	*0.721*	*0.781*	0.217	*0.287*	*0.121*
Duration of sedentary‡	-0.081	*0.687*	*0.719*	-0.243	*0.231*	*0.304*
Duration of light‡	0.052	*0.797*	*0.649*	0.182	*0.374*	*0.909*
Duration of moderate‡	0.090	*0.655*	*0.792*	0.175	*0.391*	*0.099*
Duration of vigorous‡	0.106	*0.600*	*0.387*	0.168	*0.431*	*0.354*

AEE – Activity energy expenditure (kcal/kg fat-free mass/day); ‡ minutes/day
P value[1] – Correlation coefficients on log-transformed data.
P value[2] – Adjusted for age, parity, ethnicity, DEPCAT status, working status and duration of gestation

Table 6.11b
Pearson correlation coefficients *(r)* between reported sedentary activity energy expenditure from PPAQ and accelerometry measures

Accelerometry measures	Reported sedentary activity (MET-hours/day)					
	Obese (n=27)			Lean (n=26)		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
Total steps (steps/day)	0.356	*0.068*	*0.916*	-0.420	*0.033*	*0.083*
Total activity count (counts/day)	0.378	*0.052*	*0.841*	-0.585	*0.002*	*0.005*
Total AEE	0.385	*0.047*	*0.939*	-0.599	*0.001*	*0.002*
Duration of sedentary‡	-0.492	*0.009*	*0.533*	0.402	*0.042*	*0.093*
Duration of light‡	0.407	*0.035*	*0.554*	-0.175	*0.393*	*0.600*
Duration of moderate‡	0.368	*0.059*	*0.749*	-0.462	*0.017*	*0.031*
Duration of vigorous‡	0.001	*0.994*	*0.824*	-0.512	*0.007*	*0.018*

AEE – Activity energy expenditure (kcal/kg fat-free mass/day); ‡ minutes/day
P value[1] – Correlation coefficients on log-transformed data.
P value[2] – Adjusted for age, parity, ethnicity, DEPCAT status, working status and duration of gestation

Figure 6.1a

Total activity counts (counts/day) vs reported sedentary (MET-hours/day) in obese group

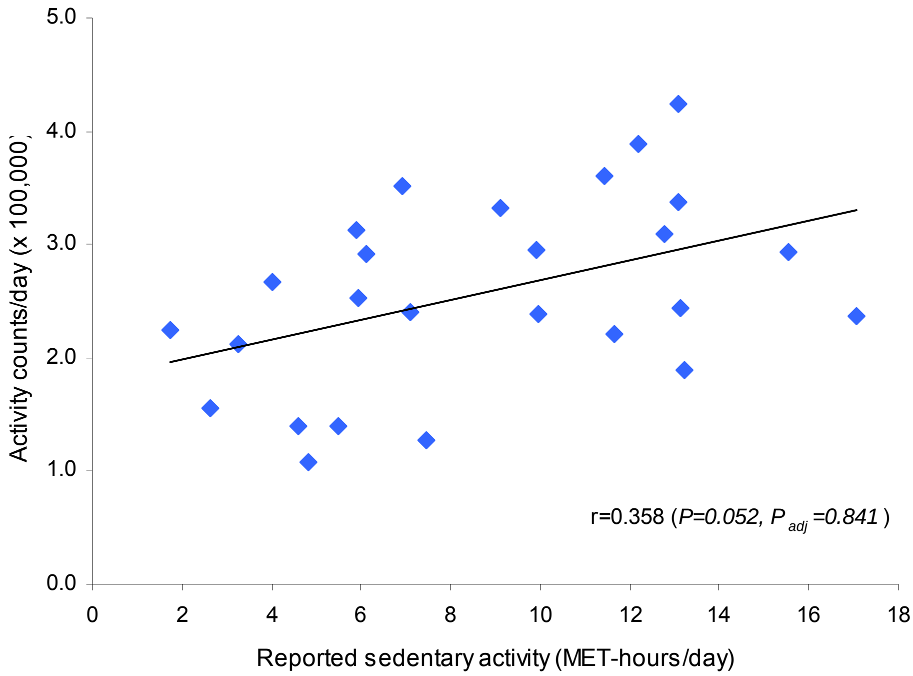


Figure 6.1b

Total activity counts (counts/day) vs reported sedentary (MET-hours/day) in lean group

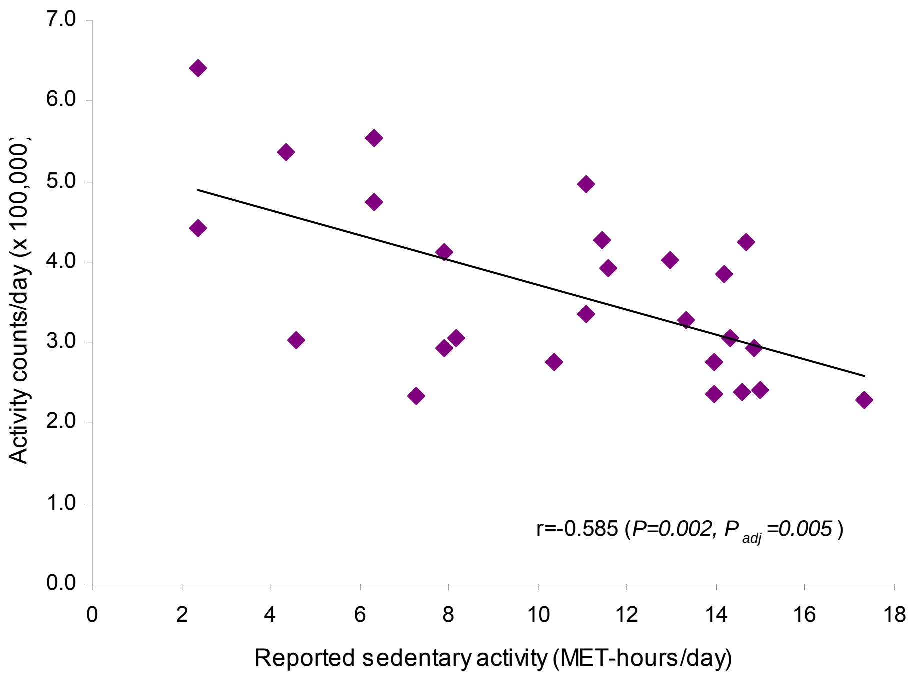


Figure 6.2a

Total activity energy expenditure (kcal/kg fat-free mass/day) vs reported sedentary (MET-hours/day) in obese group

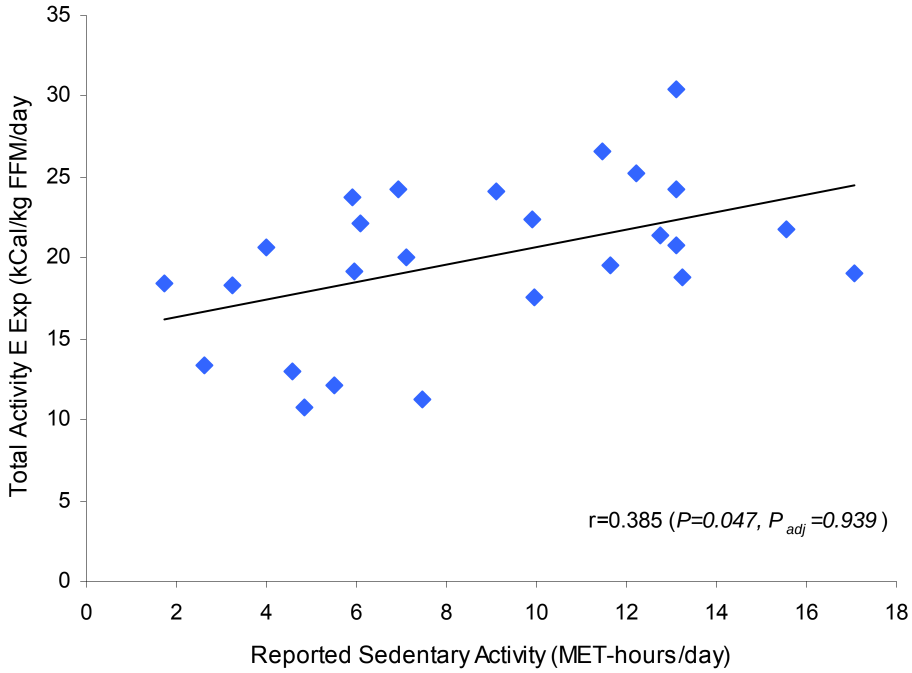


Figure 6.2b

Total activity energy expenditure (kcal/kg fat-free mass/day) vs reported sedentary (MET-hours/day) in lean group

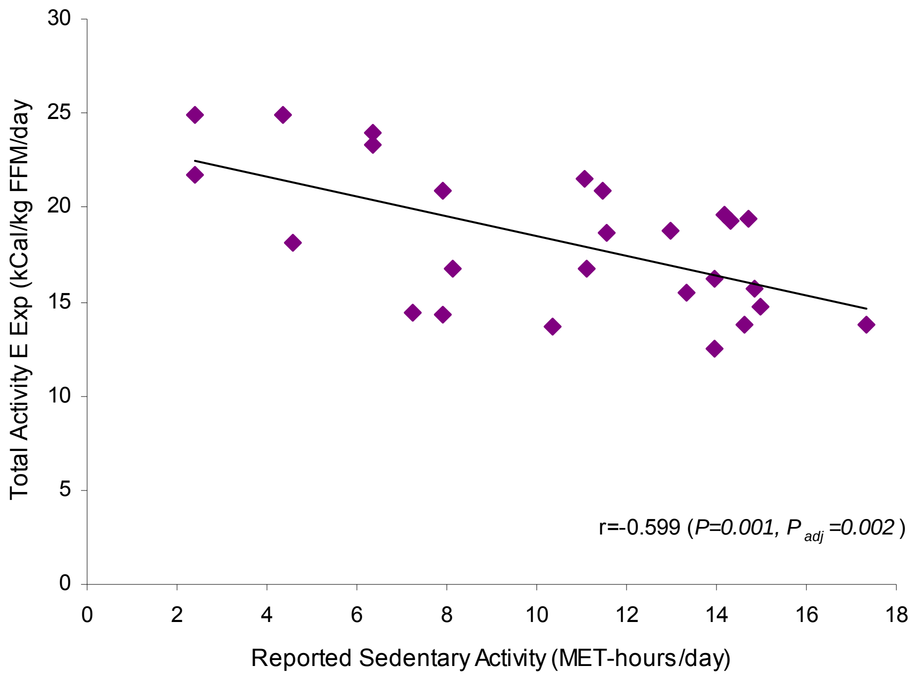


Figure 6.3a

Duration in sedentary, light, and moderate activities (minutes/day) vs reported sedentary (MET-hours/day) in obese group

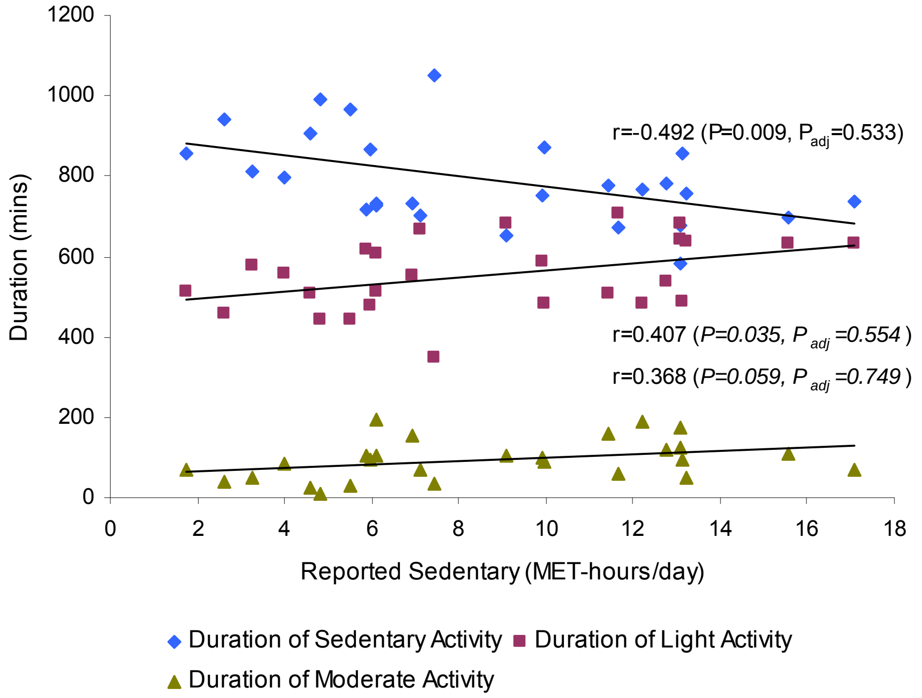
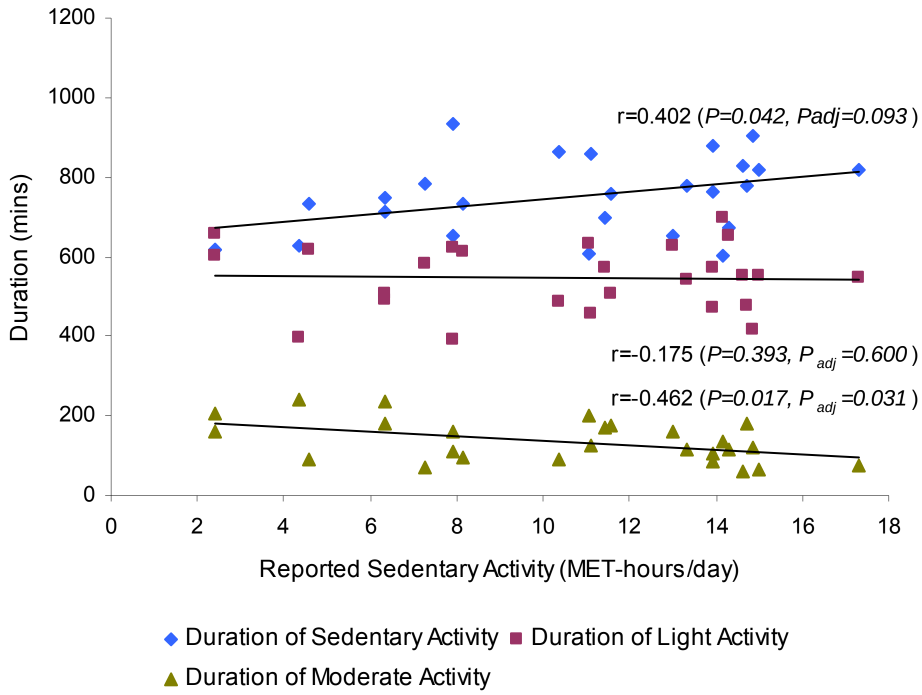


Figure 6.3b

Duration in sedentary, light, and moderate activities (minutes/day) vs reported sedentary (MET-hours/day) in lean group



6.5 Discussion

This chapter evaluated the amount, intensity and type of PA, and estimated activity energy expenditure in severely obese and lean pregnant women using a self-administered questionnaire. PA was also quantitatively assessed in a sub-group using accelerometry.

A review of 25 studies indicated that pregnant women are less active than non-pregnant women, and that pregnancy leads to a decrease in PA (Gaston and Cramp, 2011). The results from PPAQ analyses showed that both obese and lean women maintained their PA levels throughout pregnancy. Other studies in general pregnant women populations have found either a maintenance (Schmidt et al, 2006a) or a reduction (Borodulin et al, 2008, Rousham, Clarke and Gross, 2006) of total PA from early to later trimesters, using either interviewer-administered or self-reported methods to assess PA. When comparing the groups, total reported PA energy expenditure was higher in obese than lean during early pregnancy but was no longer significant after adjustment for confounders. Total PA energy expenditure was also not significantly different between obese and lean during late pregnancy. There were higher light-intensity and household/childcaring activities reported in obese than lean, but these did not persist after adjustment for confounding factors. There were significantly lower vigorous and sports/exercise activities reported in obese compared to lean throughout pregnancy. In addition, comparison against the guidelines for PA in pregnancy as recommended by the American College of Sports Medicine and the American Heart Association (Zavorsky and Longo, 2011) showed that reported sports/exercise activities were below the recommended levels for a significantly larger number of obese women, as compared to lean, both during early and late pregnancy. Maintenance of PA levels as pregnancy progresses in obese women was also reported by McParlin et al (2010) who studied 55 overweight and obese pregnant women using a questionnaire and accelerometry methods. However, they did not have a normal weight control group and they were using different cut-off points to determine their activity intensity, making data comparison with our findings impossible. Derbyshire et al (2008) reported that women were involved in more vigorous activity during early pregnancy but this was reduced with advancing gestation, a pattern also seen in our lean group although this did not reach statistical significance.

In contrast to reported PA levels, the objective assessments obtained from accelerometry showed that obese had significantly lower average activity counts/min compared to lean, although they did have significantly higher PA energy expenditure for light activity than lean, during both early and late pregnancy. There are no other studies in the literature comparing accelerometry measures between obese and lean pregnant women. However, one cross-sectional study which used a pedometer to examine total steps in 6 different groups of obese or lean in each trimester, also found that the obese group had lower total steps than lean across trimesters (Renault et al, 2010). The mean number of steps reported in their study was lower than found in the current study (early pregnancy 7,446 vs 10,026 steps/day and late pregnancy 4,626 vs 10,895 steps/day in obese; early pregnancy 8,865 vs 11,044 steps/day and late pregnancy 6,289 vs 12,105 steps/day in lean). This could be due to the different type of objective instrument used (pedometer vs accelerometer). A study on overweight and obese pregnant women using the *Actigraph* accelerometer during the first trimester also quantified lower (median) step counts/day of 5,687, with a large range between 1,545 – 11,453 (Kinnunen et al, 2011). The lower activity measures in obese compared to lean in our study are consistent with the findings of a review that indicate higher education and income, not having other children in the home, and being more active prior to pregnancy, were among the demographic predictors of higher PA participation in pregnancy (Gaston and Cramp, 2011). It has been previously shown that our obese group had significantly lower nulliparity rate (48% vs. 63%) and was of lower DEPCAT status than the lean (refer Appendix C). We did not measure pre-pregnancy PA, however, several studies did demonstrate that women with BMI>25 were 1.3-1.79 more likely to discontinue their involvements in sports/exercise after becoming pregnant (Gaston and Cramp, 2011).

The analyses of reliability of the self-reported PPAQ in estimating PA energy expenditure in severely obese pregnancy indicated that the reproducibility of the PPAQ was lower in obese, as compared to lean. The values obtained in obese group were lower than, and in lean group were comparable to, findings from a study using a similar method to validate the PPAQ in 54 pregnant women (Chasan-Taber et al, 2004), and to another which used PPAQ as one of the reference methods to validate their PA questionnaire (Schmidt et al, 2006b). This suggests poorer reproducibility of the PPAQ when used in obese pregnancy as compared to lean, or to the general pregnant women population.

In order to assess the validity of PPAQ, a summary of energy expenditures for activities as reported in the questionnaire were compared to quantitative values obtained from the accelerometer. Overall, Pearson correlation coefficients between the PPAQ and accelerometry activity counts/min were lower or comparable in the obese group and were comparable or better in the lean group, to a previous study using the same questionnaire (Chasan-Taber et al, 2004). Furthermore, correlation coefficients between accelerometry activity counts/day and self-reported total PA energy expenditure were found to be lower in obese (r=0.14) but comparable in lean (r=0.25), to findings in a general pregnant women study population (r=0.27) (Chasan-Taber et al, 2004). This suggests poorer validity of the PPAQ when used to collect PA information from obese as opposed to from lean or general pregnant women populations. Administration (self- versus interviewer-administered) and design of the questionnaire may influence validity results. A study comparing accelerometry (*Actigraph*) with the Kaiser Physical Activity Questionnaire (KPAS) found much better association between average counts/minute and total activity reported by KPAS (r=0.52) than found by Chasan-Taber et al (2004) using PPAQ (Schmidt et al, 2006b). The KPAS was interviewer-administered and was designed as a comprehensive questionnaire to measure the full range of activity in general women populations. In contrast, the PPAQ was self-administered, and was designed specifically for pregnant women as it contains selective activities which are more typical in pregnant women, and it is able to rank individuals according to their PA energy expenditure without being too lengthy (Chasan-Taber et al, 2004). It can also be speculated that overestimation occurs in self-reports of PA and this may be a result of respondents misclassifying sedentary (non-activity) as light activity, which may be the case in our obese study population. Overestimation of PA was also shown to be associated with certain populations. A study which compared a PA questionnaire to accelerometry data in 154 adults indicated that the accuracy of the questionnaire was higher in females than males, and for those with higher BMI (Ferrari, Friedrich, and Matthews, 2007). It is likely that in female and overweight/obese populations, the degree of PA over-reporting was influenced by response bias due to social desirability (Prince et al, 2008).

As expected, in the lean group, positive correlations were found between reported total activity and measured total steps, and inverse correlations were observed between reported sedentary activity and measured total PA energy expenditure and total activity counts per day. Interestingly, there was a trend for an opposite pattern for these associations in the obese group, although these were no longer significant after adjustment for confounding factors. The participants in this study were asked to wear the accelerometer after completing the PPAQ. Others have suggested that wearing a motion sensor may lead to increased awareness about PA (Haakstad, Gundersen and Bo, 2010, Chasan-Taber et al, 2004). If this was the case in the obese participants, this may have led them to consciously or subconsciously alter their PA level and become more active (or less sedentary), compared to what they reported earlier in the questionnaire.

This study is subject to several limitations. Although the PPAQ was filled in by almost all participants as it was given out routinely to all women who participate in the HIP study, only 74% of obese women approached agreed to take part in the accelerometry study and even smaller number (67%) actually completed it. Despite this, a power calculation showed that n=14 per group has 70% power to detect a significance difference of 0.05 in activity counts/min. This may have also created participation bias towards those who placed a higher value on their health and thus were more motivated to assess their own PA behaviours during pregnancy. However, the mean age and BMI of participants were comparable to those who declined. Participation response from lean pregnant women was better than obese with 88% agreeing to take part and 90% providing complete data.

The use of a self-reported questionnaire to collect PA information is subject to individuals' recall ability, personal perception and interpretation regarding PA. Interviewer-administered questionnaire may show better correlations with objective assessments (Schmidt et al, 2006b) and the presence of an interviewer may be advantageous such as in immediately checking for missing or unlikely answers (Cade et al, 2002). However, the added financial costs and time, as well as possible response-bias effect which occurs when a subject feels they are expected to give socially-desirable answers, need to be considered. For these reasons, self-administered method was chosen for the current study.

Harrison et al (2011) suggested the use of pedometers which they found to be better correlated with accelerometry results (r=0.69, $P<0.01$) as compared to the use of self-reported questionnaires (r=0.15, $P=0.44$) in 30 overweight or obese (BMI ≥25.0) pregnant women between 26-28 weeks gestation. However, in a slightly larger study (n=58, gestational week between 12-20) in a similar population, it was concluded that despite statistically significant correlations and similar median step counts between the pedometer and accelerometer, there was a substantial lack of agreement between the two monitors due to a very broad 95% limits of agreement (Kinnunen et al, 2011). This also suggests the different strengths of each monitor such as accelerometry may be more suitable to evaluate changes in moderate-to-vigorous PA, whereas pedometry may be more appropriate for walking assessment (Kinnunen et al, 2011).

The placement of the motion sensor may have influenced the results. The accelerometer should ideally be worn as close as possible to the body trunk with the best place being on hip or lower back (Trost, McIver and Pate, 2005). In the current study, due to the larger body size of participants and the study protocol which required the accelerometer to be worn for 72 consecutive hours (including all waking and sleeping hours), this was not possible without causing discomfort and so the wrist position was used. Indeed, a study comparing estimation of energy expenditure with triaxial accelerometers at four different locations showed that, although the correlation between accelerometer counts and energy expenditure was lowest on the wrist (r=0.61 vs the highest, r=0.81 on the knee), the determination coefficients of multiple regression analyses (r^2=0.851 vs the highest, r^2=0.872 on the back) did not show significant difference among the different body locations (Kim et al, 2009).

In conclusion, the findings of this study indicate poorer reproducibility and validity of the PPAQ when used in obese as compared to lean pregnant women. However, information from the PPAQ did indicate that the number of obese women who met PA recommendations during both early and late pregnancy based on reported sports and exercise activities were smaller as compared to lean pregnant women. This suggests that inactive recreational lifestyle is more prevalent in obese women despite the fact that they would potentially benefit more from the PA during pregnancy, than lean group. The PPAQ may need to be improved in terms of its assessment of the more sedentary or light-weight activities in order to enhance its suitability for use in obese pregnant women population. Whether self-reported PA impacted on gestational weight gain and birthweight is explored in the next chapter.

CHAPTER 7

Potential associations between diet/physical activity and gestational weight gain/birthweight

Chapter 7

7.1 Introduction

Obesity during pregnancy can be associated with numerous adverse maternal and fetal health outcomes, both in the short- and long-term (reviewed in Davies et al, 2010, Heslehurst et al, 2008, Catalano and Ehrenberg, 2006). These adverse pregnancy outcomes can be aggravated by excess gestational weight gain, GWG (Siega-Riz et al, 2009). Excessive weight gain during pregnancy has been associated with pregnancy complications such as the need for caesarean section, development of pregnancy-induced hypertension and diabetes, delivering large-for-gestational age or macrosomic babies, and also contributes to post-partum weight retention (Viswanathan et al, 2008, Siega-Riz, Evenson, and Dole, 2004). Therefore careful weight management during pregnancy is crucial. The latest recommendations by the Institute of Medicine, IOM (Rasmussen and Yaktine, 2009) suggest that a weight gain of between 5-9kg is optimum for all obese women during pregnancy in an effort to minimize health risks.

With ~38,500 women reported to have BMI $\geq 35 kg/m^2$ at any point in pregnancy each year in the UK (Centre for Maternal and Child Enquiries, 2010), identifying modifiable risk factors that affect GWG and birth weight (BWT) is crucial. Food intake and/or physical activity (PA) are modifiable factors that have been reported to play a role in determining GWG (Gardner et al, 2011, Stuebe et al, 2009) and weight of babies at birth (Schulz, 2010, Owe, Nystad and Bo, 2009) in general pregnant women populations. The extent to which food intake and PA impact on GWG and BWT in severely obese women, has not been investigated. The results presented in previous chapters of this thesis show that severely obese women reported to have similar total energy intake and PA energy expenditure as lean participants. However, it was also found that severely obese women misreported total energy intake and PA more than lean women. Based on the available information, the current study intended to explore the potential role of maternal diet and PA on GWG and birth outcome in this well-characterized cohort.

7.2 Hypothesis and aims

The hypothesis is that despite the similar reported total energy and PA in obese and lean women, higher caloric intake and lesser PA is associated with higher GWG and increased BWT in severely obese women.

The aims of this chapter were to assess:

a) associations between GWG/ BWT, and self-reported intakes of energy and energy-adjusted nutrients in severely obese and lean pregnant women

b) associations between GWG/BWT, and self-reported intakes of energy and energy-adjusted nutrients in a subgroup of participants in whom energy reporting accuracy had been assessed

c) associations between GWG/BWT, and self-reported PA energy expenditure, and scores of appetite and general nutrition knowledge and eating behaviour

in obese and lean pregnant women who attended the Antenatal Metabolic Clinic.

7.3 Methods

7.3.1 Study design

This is a prospective cohort study within the Energy Balance in Pregnancy (EBIP) Study.

7.3.2 Ethical approval

The EBIP study was approved by the Lothian NHS Research Ethics Committee and all subjects gave written informed consent.

7.3.3 Subject recruitment

Participants of the EBIP study were recruited from August 2008 until August 2011 (for details refer section 2.1.4.2). Subjects included in the current analysis included all those who had delivered at term (>37 weeks) by August 31st 2011.

7.3.4 Weight Measurement

Weight was measured in kilograms during the first visit (between weeks 12 to 20) and 36-week visit to the clinic by using a SECA 959 chair weighing scale (SECA Ltd, Birmingham, UK) as detailed in Section 2.4.3.

GWG was computed as the difference between weights measured during the first and 36-weeks visit. GWG status for each subject was determined by comparing GWG against the IOM guidelines (Rasmussen and Yaktine, 2009, refer Table 1.1) and subject was categorized as having inadequate, adequate, or excess GWG.

BWT of babies was obtained from birth records (online database). 2 babies (born to 1 obese and 1 lean mothers) who were delivered prematurely (<37 gestational weeks) were excluded.

7.3.5 Energy and nutrients intakes

Food intake was measured using a semi-quantitative Scottish Collaborative Group Food Frequency Questionnaire (SCG-FFQ) version 6.6 (Scottish Collaborative Group, University of Aberdeen, UK). This was completed twice; early pregnancy (during first visit) and late pregnancy (28-week visit) as detailed in Section 2.5.1.

7.3.6 Physical Activity Energy Expenditure

PA energy expenditure was assessed by using the validated Pregnancy Physical Activity Questionnaire (PPAQ), an instrument which was developed specifically for pregnant women (Chasan-Taber et al, 2004). This was completed twice; early pregnancy (during first visit) and late pregnancy (28-week visit) as detailed in Section 2.6.1.

7.3.7 General nutrition knowledge scores

Levels of nutrition knowledge in study participants were evaluated by using a validated General Nutrition Knowledge Questionnaire, GNKQ (Parmenter and Wardle, 1999) as detailed in Section 2.5.3.

7.3.8 Appetite scores

A subgroup of the study volunteers was asked to complete the Council on Nutrition Appetite Questionnaire, CNAQ (Wilson et al, 2005). This questionnaire was completed twice during pregnancy, during first and 28-week visits as detailed in Section 2.5.4.

7.3.9 Eating behaviour scores

The Dutch Eating Behaviour Questionnaire (DEBQ) was used to assess three types of eating behaviour (restraint, emotional, and externally cued eating behaviours (van Strien et al, 1986) as detailed in Section 2.5.5.

7.3.10 Determination of energy reporting accuracy

To determine the degree of misreporting for each person, the energy intake: estimated energy requirement (EI:EER) ratio was calculated using total energy intake (kcal/day) as reported in SCG-FFQ completed during 28-weeks visit, divided by the EER calculated using the IOM 1992's Dietary Reference Intake equations (details are presented in Section 5.3.7). Each person was then categorized as either an under-reporter, adequate reporter, or over-reporter by using published cut off-points for lean and obese (Nowicki et al, 2011).

7.3.11 Maternal characteristics

Information such as age, parity, and Deprivation Category (DEPCAT) status based on postcodes (McLoone, 2003), were obtained from personal background and lifestyle questionnaires completed by participants during the first study visit.

7.3.12 Data Analysis

Data from completed SCG-FFQ were entered into a Microsoft Access entry package provided by the questionnaire administrator and were exported to the administrator to be analyzed (as detailed in Section 2.1.9.1). The PPAQ was analyzed manually, following instructions provided by the main developer of the questionnaire (Chasan-Taber, 2004) (as detailed in Section 2.7.5). The GNKQ was analyzed manually following the answer scheme as provided by the questionnaire's developer (Parmenter and Wardle, 1999) as detailed in Section 2.7.3. The CNAQ was analyzed manually (as detailed in Section 2.7.4) following the instructions provided in a publication that discussed the use of this questionnaire (Wilson et al, 2005). The DEBQ was analyzed manually according to methods published by the questionnaire's developer (van Strien et al, 1986) as detailed in Section 2.7.5.

7.3.13 Statistical methods

Normal distribution of data was assessed visually using histograms and Q-Q plots, and by using Kolmogorov-Smirnov test. Self-reported total energy and nutrient intakes, and PA data, were not normally distributed and were normalized by using natural log transformation. The distributions of BWT, GWG, as well as appetite, general nutrition knowledge, and eating behaviour scores were normal.

Nutrient intakes were adjusted for total energy intake by using the residual method calculated from regression of nutrient intake as the dependent variable and total energy as the independent variable (Willet and Stampfer, 1986). Nutrient intakes from dietary supplements were not included in any of the analyses. Associations between variables were tested using Pearson correlation coefficients. Comparison of GWG and BWT among categories of energy reporting accuracy (under, adequate, and over-reporters) was analyzed by using analysis of variance F test (ANOVA). Proportions of participants (within and between groups) according to GWG status based on the IOM guidelines (Rasmussen and

Yaktine, 2009, refer Table 1.1), and BWT status, (within and between groups) were tested by using chi square test.

The significance level was set at 5% and all statistical analyses were performed using SPSS version 14.0 (SPSS Inc., Chicago, IL, USA). All results were adjusted for demographic confounding factors such as age, parity, ethnicity, and DEPCAT status. BWT results were also adjusted for baby gender, duration of gestation and maternal height. PA variables were additionally adjusted for working status and general nutrition knowledge adjusted for marital status and education level. In the subgroup of obese and lean subjects with assessment of energy misreporting, total energy and nutrients were also adjusted for reporting accuracy categories. These adjustments were done using linear regression analysis.

7.4 Results

The demographic characteristics of all subjects who were included in this study are presented in Table 7.1. Overall, both obese and lean participants who were included in this study were found to be largely representative of the larger HIP cohort. However, a higher percentage of the obese participants were of middle and high DEPCAT status than obese participants who did not take part in this study (refer Appendix L).

Table 7.1

Demographic characteristics of all subjects who were included in this study

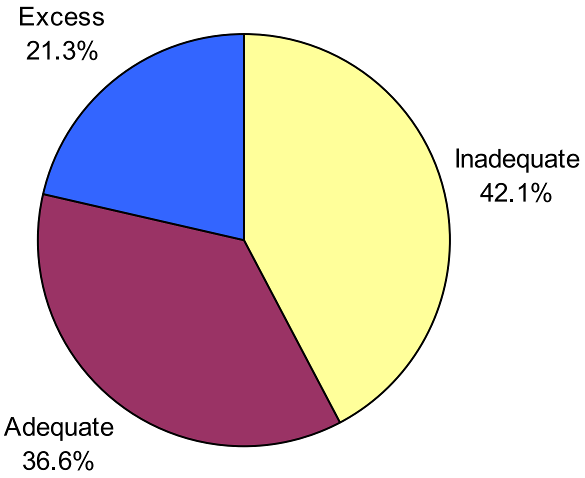
		Obese (n=175)		Lean (n=87)		
		Mean	(Range or %)	Mean	(Range or %)	*P Value*
Age (years)		31.4	(19.8 – 44.5)	33.4	(18.2 – 42.3)	*P=0.004*‡
BMI at booking (kg/m^2)		44.1	(37.9 – 61.1)	22.6	(19.4 – 27.6)	*P<0.001*‡
Parity	Nulliparous	83	(48.3%)	55	(63.2%)	*P=0.025*†
	Multiparous	89	(51.7%)	32	(36.8%)	
Ethnicity	Caucasian	167	(95.4%)	87	(100%)	*P=0.055*†
	Non-Caucasian	8	(4.6%)			
DEPCAT status	Low	27	(15.5%)	1	(1.1%)	*P<0.001*†
	Middle	133	(76.4%)	60	(69.0%)	
	High	14	(8.0%)	26	(29.9%)	
Birth weight (g)		3,572	(2,140 – 4,880)	3,579	(2,620 – 5,020)	*P=0.150**
Baby gender	Male	77	(47.2%)	38	(52.8%)	*P=0.434*†
	Female	86	(52.8%)	34	(47.2%)	
Duration of gestation (days)		279	(251 - 295)	283	(256 - 295)	*P=0.009*‡
Maternal height (meters)		1.64	(1.46 – 1.86)	1.67	(1.54 – 1.83)	*P=0.003*‡

‡ Tested using independent t-test; † Tested using chi square test; DEPCAT – Deprivation Category
* Using linear regression (adjusted for maternal age, ethnicity, parity, DEPCAT status, baby gender, duration of gestation, and maternal height.

GWG data were available for 164 obese and 80 lean women. Between the first and 36-weeks visits, obese women only gained about half as much weight as their lean counterparts (Mean ± SD, 5.6 ± 5.3 vs 10.7 ± 3.6 kg, $P<0.001$). Based on the IOM 2009 guidelines (Rasmussen and Yaktine, 2010), the proportions of GWG status in obese were: 42% inadequate, 37% adequate, and 21% excess, compared to in lean: 56% inadequate, 34% adequate, and 10% excess (Figures 7.1a and 7.1b). The GWG status was significantly different within each group (obese $P=0.001$; lean $P<0.001$), as well as between groups ($P=0.042$, $P_{adj}=0.002$).

Figure 7.1a

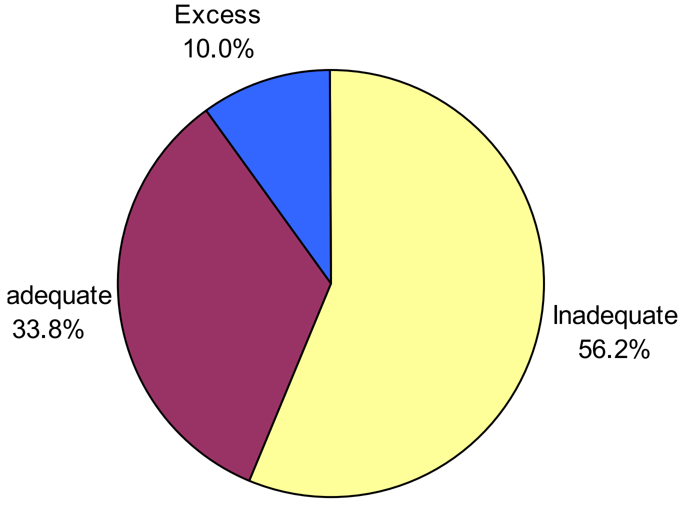
Gestational weight status based on Institute of Medicine 2009 GWG guidelines in obese group (n=164)



Significance within group (chi square test): *P=0.001*

Figure 7.1b

Gestational weight status based on Institute of Medicine 2009 GWG guidelines in lean group (n=80)

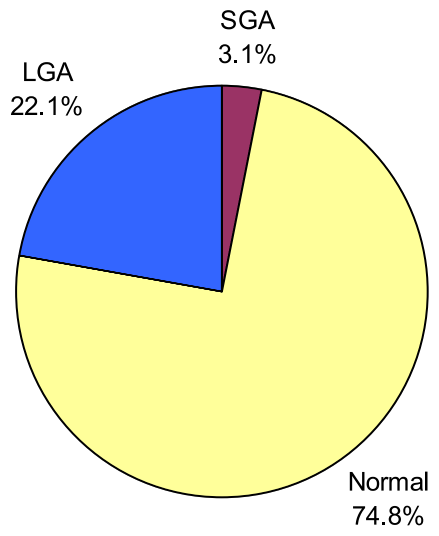


Significance within group (chi square test): *P<0.001*

BWT data were available for 163 obese and 72 lean women. BWT (adjusted for baby gender, gestation duration and maternal height) was not significantly different between obese and lean groups (Table 7.1). Among obese mothers, 3% of them delivered small-for-gestational age (SGA, defined as BWT <2,500g) and 22% delivered large-for-gestational age (LGA, defined as BWT ≥4,000g) babies (Figure 7.2a). In lean, no babies were born SGA and 15% were born with LGA (Figure 7.2b). The BWT status was significantly different within each group (both $P<0.001$), but not between groups ($P=0.146$, $P_{adj}=0.079$). GWG was positively associated with BWT in lean, but no correlation was observed in obese (Figures 7.3a and 7.3b).

Figure 7.2a

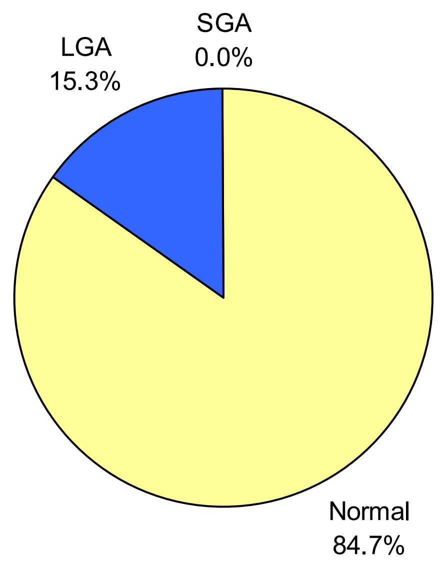
Offspring birth weight status in obese group (n=163)



SGA – Small-for-gestational age; LGA – Large-for-gestational age

Figure 7.2b

Offspring birth weight status in lean group (n=72)



SGA – Small-for-gestational age; LGA – Large-for-gestational age

Figure 7.3a

Lack of association between gestational weight gain and baby birth weight in obese group (n=153)

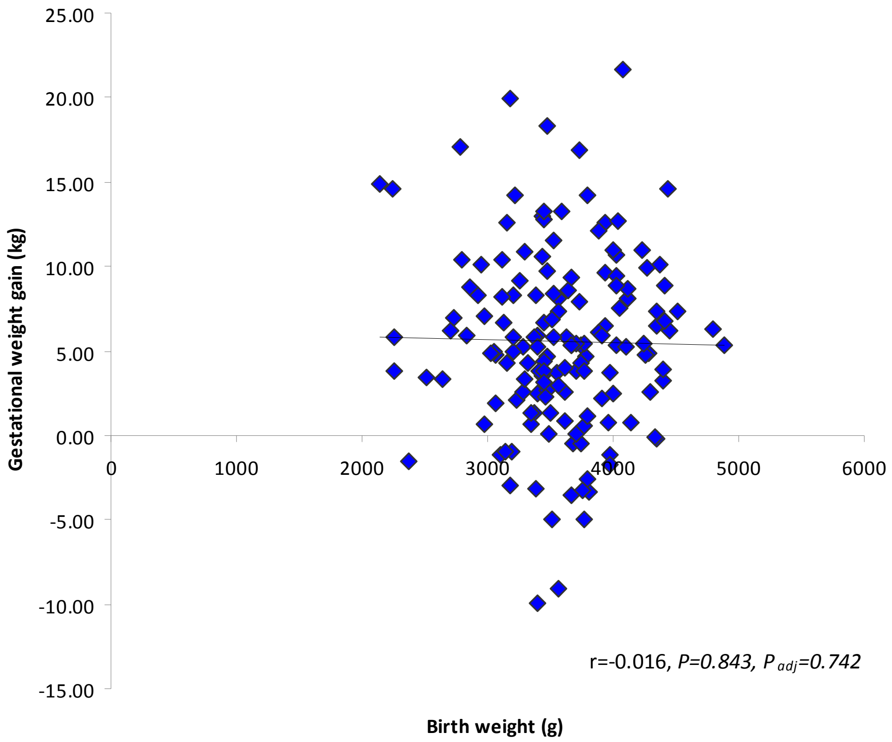
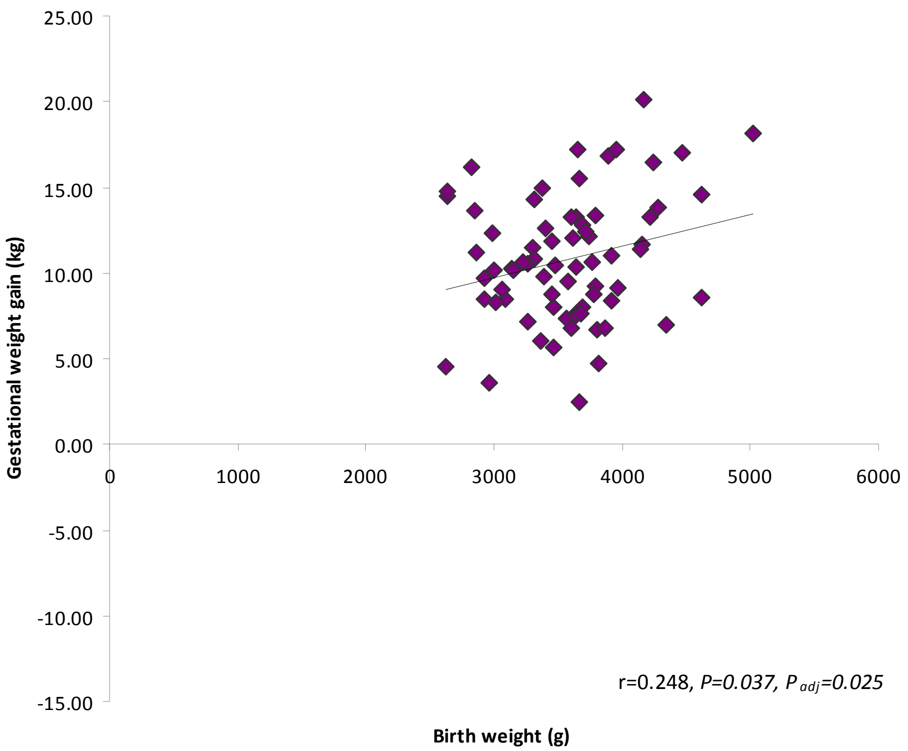


Figure 7.3b

Positive association between gestational weight gain and baby birth weight in lean group (n=71)



Data for GWG and food intake was provided by 132 obese and 74 lean in early pregnancy, and by 133 obese and 68 lean in late pregnancy. As shown in Table 7.2a, in the obese group, increased GWG was significantly associated with increased intakes of dietary cholesterol, selenium, retinol and vitamins D and B_{12} in early pregnancy, and increased total carbohydrate, dietary cholesterol and vitamin B_6 in late pregnancy, (all $P_{adj}<0.05$). In lean (Table 7.2b), GWG was positively associated with total calories, total fat, saturated fatty acids (SFA), and monounsaturated fatty acids (MUFA), and inversely associated with total carbohydrate intake, throughout pregnancy (all $P_{adj}<0.05$). Other than that, significant associations were also seen between total GWG and early pregnancy intakes of sugars, retinol, thiamine, riboflavin and folic acid in the lean group.

BWT data was compared with food intake data during early pregnancy in 129 obese and 66 lean women, and during late pregnancy in 132 obese and 67 lean pregnant women. Only late pregnancy intake of β-carotene was significantly associated with BWT in the obese group (Table 7.3a). In lean (Table 7.3b), BWT was found to increase with increasing total energy intake in late pregnancy ($P_{adj}=0.003$). BWT was also positively correlated with starch intake ($P_{adj}=0.042$) but inversely associated with sugars intake ($P_{adj}=0.023$) in late pregnancy in this group.

Table 7.2a

Pearson correlation coefficients *(r)* between gestational weight gain* and maternal reported food intake (early and late pregnancy) in obese group

Nutrient	Early Pregnancy (n=132)			Late Pregnancy (n=133)		
	r	*P value[1]*	*P value[2]*	*r*	*P value[1]*	*P value[2]*
Energy (kcal)	0.116	*0.202*	*0.282*	0.137	*0.120*	*0.377*
Protein (g)	0.128	*0.161*	*0.058*	0.103	*0.240*	*0.128*
Fat (g)	-0.030	*0.740*	*0.903*	0.155	*0.078*	*0.156*
Carbohydrate (g)	-0.023	*0.800*	*0.512*	0.180	*0.040*	*0.048*
SFA (g)	0.014	*0.878*	*0.570*	0.173	*0.048*	*0.133*
MUFA (g)	-0.042	*0.649*	*0.564*	0.170	*0.053*	*0.117*
PUFA (g)	0.003	*0.970*	*0.845*	0.018	*0.842*	*0.705*
Cholesterol (mg)	0.116	*0.203*	*0.032*	0.206	*0.018*	*0.038*
Sugars (g)	0.089	*0.330*	*0.787*	0.118	*0.179*	*0.164*
Starch (g)	-0.135	*0.138*	*0.432*	0.068	*0.442*	*0.531*
Fibre (g)	0.115	*0.207*	*0.502*	0.213	*0.015*	*0.169*
Sodium (mg)	0.060	*0.515*	*0.740*	0.005	*0.951*	*0.866*
Potassium (mg)	0.103	*0.257*	*0.483*	0.075	*0.394*	*0.797*
Calcium (mg)	0.048	*0.596*	*0.505*	-0.013	*0.883*	*0.355*
Magnesium (mg)	0.071	*0.440*	*0.529*	0.127	*0.147*	*0.568*
Phosphorus (mg)	-0.030	*0.741*	*0.948*	-0.113	*0.201*	*0.156*
Iron (mg)	0.109	*0.232*	*0.746*	0.224	*0.010*	*0.579*
Copper (mg)	-0.034	*0.712*	*0.932*	0.034	*0.701*	*0.826*
Zinc (mg)	0.133	*0.145*	*0.060*	-0.059	*0.500*	*0.371*
Chloride (mg)	0.072	*0.432*	*0.729*	-0.037	*0.677*	*0.569*
Manganese (mg)	0.026	*0.774*	*0.939*	0.079	*0.372*	*0.761*
Selenium (µg)	0.216	*0.017*	*0.013*	0.018	*0.838*	*0.653*
Iodine (µg)	0.112	*0.221*	*0.122*	-0.073	*0.405*	*0.229*
Retinol (µg)	0.163	*0.073*	*0.016*	-0.083	*0.348*	*0.760*
B-carotene equ (µg)	0.089	*0.328*	*0.748*	0.152	*0.083*	*0.152*
Vitamin D (µg)	0.243	*0.007*	*0.010*	0.054	*0.538*	*0.440*
Vitamin E (mg)	0.075	*0.412*	*0.790*	0.076	*0.391*	*0.712*
Thiamine (mg)	0.078	*0.393*	*0.456*	-0.008	*0.925*	*0.962*
Riboflavin (mg)	0.028	*0.760*	*0.560*	-0.069	*0.432*	*0.331*
Niacin (mg)	0.089	*0.332*	*0.261*	0.067	*0.450*	*0.746*
Potential niacin (mg)	0.136	*0.136*	*0.058*	0.157	*0.074*	*0.170*
Vitamin B6 (mg)	0.120	*0.189*	*0.126*	0.195	*0.025*	*0.041*
Vitamin B12 (µg)	0.223	*0.014*	*0.003*	-0.067	*0.446*	*0.381*
Folic acid (µg)	0.080	*0.381*	*0.505*	0.095	*0.281*	*0.621*
Pantothenic acid (mg)	0.040	*0.662*	*0.407*	-0.101	*0.251*	*0.246*
Biotin (µg)	0.099	*0.279*	*0.380*	-0.033	*0.705*	*0.447*
Vitamin C (mg)	0.193	*0.033*	*0.266*	0.160	*0.067*	*0.329*
Vitamin K (µg)	0.178	*0.050*	*0.229*	0.105	*0.231*	*0.626*
Alcohol	0.010	*0.917*	*0.720*	-0.109	*0.215*	*0.159*

* Calculated as the difference between weight at first visit and 36-weeks visit
P value [1] – log-transformed data, adjusted for energy intake
P value [2] – log-transformed data, adjusted for energy intake, age, parity, ethnicity, DEPCAT status

Table 7.2b

Pearson correlation coefficients *(r)* between gestational weight gain* and maternal reported food intake (early and late pregnancy) in lean group

Nutrient	Early Pregnancy (n=74)			Late Pregnancy (n=68)		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
Energy (kcal)	0.301	*0.009*	*0.006*	0.281	*0.021*	*0.011*
Protein (g)	0.113	*0.336*	*0.285*	0.044	*0.721*	*0.713*
Fat (g)	0.409	*<0.001*	*<0.001*	0.331	*0.006*	*0.005*
Carbohydrate (g)	-0.327	*0.004*	*0.006*	-0.286	*0.018*	*0.013*
SFA (g)	0.346	*0.003*	*0.002*	0.289	*0.017*	*0.020*
MUFA (g)	0.396	*<0.001*	*0.001*	0.305	*0.011*	*0.011*
PUFA (g)	0.277	*0.017*	*0.019*	0.134	*0.312*	*0.190*
Cholesterol (mg)	0.265	*0.048*	*0.060*	0.212	*0.103*	*0.146*
Sugars (g)	-0.275	*0.018*	*0.029*	-0.216	*0.100*	*0.094*
Starch (g)	-0.047	*0.732*	*0.632*	-0.108	*0.415*	*0.468*
Fibre (g)	-0.174	*0.139*	*0.116*	-0.255	*0.051*	*0.081*
Sodium (mg)	0.213	*0.114*	*0.122*	-0.020	*0.880*	*0.949*
Potassium (mg)	-0.304	*0.023*	*0.031*	-0.278	*0.033*	*0.074*
Calcium (mg)	-0.045	*0.739*	*0.677*	-0.150	*0.221*	*0.236*
Magnesium (mg)	0.211	*0.118*	*0.166*	-0.187	*0.127*	*0.129*
Phosphorus (mg)	-0.033	*0.811*	*0.761*	-0.231	*0.058*	*0.080*
Iron (mg)	-0.247	*0.034*	*0.020*	-0.146	*0.235*	*0.243*
Copper (mg)	0.026	*0.850*	*0.779*	0.178	*0.177*	*0.176*
Zinc (mg)	0.047	*0.732*	*0.893*	0.052	*0.694*	*0.615*
Chloride (mg)	0.172	*0.205*	*0.222*	0.032	*0.810*	*0.644*
Manganese (mg)	-0.179	*0.186*	*0.241*	-0.225	*0.086*	*0.139*
Selenium (µg)	-0.082	*0.550*	*0.503*	0.001	*0.995*	*0.967*
Iodine (µg)	-0.131	*0.334*	*0.390*	-0.110	*0.409*	*0.411*
Retinol (µg)	0.320	*0.016*	*0.020*	0.189	*0.153*	*0.179*
B-carotene equ (µg)	-0.171	*0.301*	*0.240*	0.017	*0.901*	*0.851*
Vitamin D (µg)	-0.002	*0.991*	*0.913*	0.094	*0.478*	*0.575*
Vitamin E (mg)	0.028	*0.837*	*0.795*	-0.159	*0.229*	*0.260*
Thiamine (mg)	-0.284	*0.034*	*0.026*	-0.179	*0.174*	*0.203*
Riboflavin (mg)	-0.299	*0.025*	*0.019*	-0.214	*0.104*	*0.125*
Niacin (mg)	0.077	*0.959*	*0.913*	0.072	*0.586*	*0.604*
Potential niacin (mg)	0.225	*0.096*	*0.151*	0.143	*0.282*	*0.321*
Vitamin B6 (mg)	-0.125	*0.359*	*0.338*	-0.015	*0.910*	*0.876*
Vitamin B12 (µg)	-0.014	*0.918*	*0.774*	0.112	*0.399*	*0.463*
Folic acid (µg)	-0.221	*0.038*	*0.037*	-0.146	*0.269*	*0.372*
Pantothenic acid (mg)	-0.134	*0.327*	*0.253*	-0.080	*0.548*	*0.646*
Biotin (µg)	-0.263	*0.050*	*0.073*	-0.262	*0.045*	*0.089*
Vitamin C (mg)	-0.137	*0.313*	*0.287*	0.023	*0.864*	*0.678*
Vitamin K (µg)	-0.022	*0.872*	*0.772*	-0.005	*0.970*	*0.926*
Alcohol	-0.056	*0.684*	*0.847*	-0.053	*0.291*	*0.360*

* Calculated as the difference between weight at first visit and 36-weeks visit
P value [1] – log-transformed data, adjusted for energy intake
P value [2] – log-transformed data, adjusted for energy intake, age, parity, ethnicity, DEPCAT status

Table 7.3a

Pearson correlation coefficients *(r)* between birth weight and maternal reported food intake (early and late pregnancy) in obese group

Nutrient	Early Pregnancy (n=129)			Late Pregnancy (n=132)		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
Energy (kcal)	0.124	*0.182*	*0.510*	0.117	*0.181*	*0.328*
Protein (g)	0.074	*0.431*	*0.904*	0.122	*0.165*	*0.340*
Fat (g)	0.007	*0.943*	*0.584*	0.025	*0.773*	*0.483*
Carbohydrate (g)	0.006	*0.946*	*0.439*	-0.054	*0.537*	*0.720*
SFA (g)	-0.028	*0.765*	*0.522*	0.037	*0.671*	*0.377*
MUFA (g)	0.010	*0.913*	*0.485*	0.029	*0.742*	*0.498*
PUFA (g)	0.003	*0.976*	*0.801*	0.013	*0.884*	*0.864*
Cholesterol (mg)	0.062	*0.504*	*0.956*	0.492	*0.575*	*0.993*
Sugars (g)	-0.056	*0.550*	*0.775*	-0.065	*0.456*	*0.695*
Starch (g)	0.121	*0.194*	*0.357*	0.029	*0.756*	*0.385*
Fibre (g)	-0.016	*0.864*	*0.983*	0.003	*0.976*	*0.324*
Sodium (mg)	0.113	*0.224*	*0.300*	0.108	*0.238*	*0.206*
Potassium (mg)	-0.018	*0.844*	*0.448*	0.004	*0.965*	*0.678*
Calcium (mg)	0.087	*0.351*	*0.571*	-0.001	*0.991*	*0.911*
Magnesium (mg)	-0.005	*0.955*	*0.812*	0.011	*0.906*	*0.241*
Phosphorus (mg)	0.062	*0.510*	*0.930*	0.096	*0.293*	*0.377*
Iron (mg)	0.061	*0.515*	*0.402*	0.054	*0.555*	*0.128*
Copper (mg)	-0.023	*0.808*	*0.982*	-0.082	*0.370*	*0.918*
Zinc (mg)	0.045	*0.627*	*0.819*	0.060	*0.517*	*0.640*
Chloride (mg)	0.099	*0.290*	*0.421*	0.143	*0.117*	*0.143*
Manganese (mg)	0.051	*0.584*	*0.283*	0.037	*0.684*	*0.154*
Selenium (µg)	0.040	*0.671*	*0.691*	0.167	*0.067*	*0.073*
Iodine (µg)	0.138	*0.138*	*0.493*	0.154	*0.091*	*0.228*
Retinol (µg)	0.086	*0.358*	*0.649*	0.001	*0.990*	*0.378*
B-carotene equ (µg)	0.064	*0.495*	*0.084*	0.148	*0.105*	*0.030*
Vitamin D (µg)	-0.001	*0.991*	*0.466*	0.119	*0.194*	*0.343*
Vitamin E (mg)	-0.026	*0.783*	*0.928*	0.015	*0.869*	*0.655*
Thiamine (mg)	0.105	*0.261*	*0.663*	0.133	*0.146*	*0.076*
Riboflavin (mg)	0.114	*0.223*	*0.881*	0.116	*0.204*	*0.334*
Niacin (mg)	0.004	*0.962*	*0.391*	0.167	*0.056*	*0.089*
Potential niacin (mg)	0.090	*0.335*	*0.934*	0.105	*0.252*	*0.369*
Vitamin B6 (mg)	-0.037	*0.692*	*0.226*	0.118	*0.197*	*0.212*
Vitamin B12 (µg)	0.048	*0.607*	*0.993*	0.128	*0.160*	*0.434*
Folic acid (µg)	0.094	*0.315*	*0.532*	0.075	*0.412*	*0.194*
Pantothenic acid (mg)	0.082	*0.379*	*0.973*	0.133	*0.145*	*0.263*
Biotin (µg)	0.129	*0.165*	*0.766*	0.098	*0.287*	*0.456*
Vitamin C (mg)	-0.058	*0.538*	*0.799*	-0.034	*0.711*	*0.890*
Vitamin K (µg)	0.058	*0.534*	*0.306*	-0.010	*0.914*	*0.588*
Alcohol	-0.040	*0.667*	*0.929*	-0.113	*0.197*	*0.375*

P value [1] – log-transformed data, adjusted for energy intake
P value [2] – log-transformed data, adjusted for energy intake, age, parity, ethnicity, DEPCAT status

Table 7.3b

Pearson correlation coefficients *(r)* between birth weight and maternal reported food intake (early and late pregnancy) in lean group

Nutrient	Early Pregnancy (n=66)			Late Pregnancy (n=67)		
	r	*P value[1]*	*P value[2]*	*r*	*P value[1]*	*P value[2]*
Energy (kcal)	0.208	*0.093*	*0.134*	0.409	*0.001*	*0.003*
Protein (g)	0.092	*0.463*	*0.530*	0.164	*0.189*	*0.276*
Fat (g)	0.017	*0.894*	*0.688*	0.086	*0.488*	*0.854*
Carbohydrate (g)	-0.035	*0.794*	*0.782*	-0.153	*0.217*	*0.525*
SFA (g)	-0.019	*0.881*	*0.914*	0.026	*0.836*	*0.756*
MUFA (g)	0.035	*0.780*	*0.495*	0.085	*0.493*	*0.923*
PUFA (g)	0.088	*0.483*	*0.411*	0.229	*0.062*	*0.369*
Cholesterol (mg)	0.099	*0.475*	*0.875*	0.136	*0.273*	*0.759*
Sugars (g)	-0.130	*0.300*	*0.353*	-0.310	*0.011*	*0.023*
Starch (g)	0.189	*0.128*	*0.238*	0.219	*0.075*	*0.042*
Fibre (g)	-0.063	*0.617*	*0.242*	0.011	*0.932*	*0.846*
Sodium (mg)	0.157	*0.257*	*0.391*	0.151	*0.265*	*0.259*
Potassium (mg)	-0.058	*0.679*	*0.171*	0.129	*0.344*	*0.147*
Calcium (mg)	0.080	*0.566*	*0.636*	-0.015	*0.902*	*0.630*
Magnesium (mg)	0.057	*0.683*	*0.803*	0.107	*0.432*	*0.528*
Phosphorus (mg)	0.045	*0.745*	*0.803*	0.030	*0.826*	*0.775*
Iron (mg)	0.074	*0.596*	*0.153*	0.125	*0.315*	*0.291*
Copper (mg)	0.177	*0.201*	*0.198*	0.131	*0.336*	*0.151*
Zinc (mg)	0.171	*0.216*	*0.312*	0.164	*0.227*	*0.142*
Chloride (mg)	0.208	*0.132*	*0.319*	0.172	*0.205*	*0.229*
Manganese (mg)	0.107	*0.440*	*0.969*	0.152	*0.262*	*0.675*
Selenium (µg)	-0.184	*0.184*	*0.116*	-0.039	*0.753*	*0.430*
Iodine (µg)	-0.041	*0.768*	*0.595*	-0.046	*0.714*	*0.195*
Retinol (µg)	0.058	*0.679*	*0.938*	0.049	*0.692*	*0.729*
B-carotene equ (µg)	-0.118	*0.397*	*0.121*	0.005	*0.970*	*0.568*
Vitamin D (µg)	-0.033	*0.810*	*0.804*	0.005	*0.996*	*0.546*
Vitamin E (mg)	0.040	*0.772*	*0.994*	-0.032	*0.813*	*0.272*
Thiamine (mg)	0.053	*0.705*	*0.582*	0.207	*0.127*	*0.088*
Riboflavin (mg)	0.029	*0.833*	*0.652*	0.053	*0.700*	*0.977*
Niacin (mg)	0.068	*0.624*	*0.525*	0.189	*0.164*	*0.136*
Potential niacin (mg)	0.186	*0.179*	*0.130*	0.117	*0.390*	*0.387*
Vitamin B6 (mg)	0.065	*0.640*	*0.895*	0.066	*0.629*	*0.839*
Vitamin B12 (µg)	0.002	*0.990*	*0.674*	0.002	*0.990*	*0.324*
Folic acid (µg)	0.058	*0.679*	*0.939*	0.157	*0.247*	*0.461*
Pantothenic acid (mg)	0.021	*0.882*	*0.947*	0.051	*0.709*	*0.621*
Biotin (µg)	0.017	*0.904*	*0.940*	0.075	*0.580*	*0.922*
Vitamin C (mg)	-0.030	*0.830*	*0.511*	-0.065	*0.225*	*0.240*
Vitamin K (µg)	0.090	*0.518*	*0.587*	0.042	*0.759*	*0.437*
Alcohol	0.032	*0.796*	*0.746*	0.071	*0.567*	*0.824*

P value [1] – log-transformed data, adjusted for energy intake
P value [2] – log-transformed data, adjusted for energy intake, age, parity, ethnicity, DEPCAT status

A subgroup of the study population had been included in a cross-sectional study which assessed the accuracy of their energy intake self-reporting (as presented in Chapter 5 of this thesis). Whether GWG (n=98 obese and 68 lean) and BWT (n=97 obese and 65 lean) differed according to reporting accuracy categories was tested. The correlations of GWG and BWT with intakes of energy and other nutrients were also tested after adjusting for reporting accuracy. Among the lean group (Tables 7.4b and 7.4d), GWG and BWT were found to be the lowest in those who under-reported total energy intake and highest in over-reporters (all $P_{adj}<0.01$), although the significance for difference in BWT did not persist after adjustment for potential confounders. There were no differences in GWG or BWT according to accuracy of reporting in the obese group (Tables 7.4a and 7.4c). In the obese group, other than the positive association between GWG and β-carotene intake, GWG and BWT were not associated with either intake of calories or nutrients after adjusting for reporting accuracy (Tables 7.5a and 7.5b). In the lean group (Table 7.5a), however, the positive correlation between GWG and total fat, and monounsaturated fatty acid (MUFA) intakes, and the inverse association between GWG and riboflavin intake, remained significant after adjustment for reporting accuracy (all $P_{adj}<0.05$). Likewise, BWT in lean (Table 7.5b) was positively associated with intakes of total energy, starch, iron, zinc, and thiamine, and inversely associated with intake of sugars after adjustment for reporting accuracy (all $P_{adj}<0.05$).

Table 7.4a

Mean (standard error mean, SEM) of gestational weight gain (GWG) according to energy intake reporting accuracy status in obese group

	Under-reporters (n=48)		Adequate reporters (n=43)		Over-reporters (n=7)			
	Mean	SEM	Mean	SEM	Mean	SEM	*P value* [1]	*P value* [2]
GWG*	5.2	0.9	5.8	0.8	7.1	1.9	*0.709*	*0.733*

* Calculated as the difference between weight at first visit and 36-weeks visit
P value [1] – one-way ANOVA
P value [2] – adjusted for age, parity, ethnicity and DEPCAT status

Table 7.4b

Mean (standard error mean, SEM) of gestational weight gain (GWG) according to energy intake reporting accuracy status in lean group

	Under-reporters (n=10)		Adequate reporters (n=49)		Over-reporters (n=9)			
	Mean	SEM	Mean	SEM	Mean	SEM	*P value* [1]	*P value* [2]
GWG*	9.6	1.1	10.0	0.5	14.3	1.3	*0.002*	*0.006*

* Calculated as the difference between weight at first visit and 36-weeks visit
P value [1] – one-way ANOVA
P value [2] – adjusted for age, parity, ethnicity and DEPCAT status

Table 7.4c

Mean (standard error mean, SEM) of birth weight (BWT) according to energy intake reporting accuracy status in obese group

	Under-reporters (n=47)		Adequate reporters (n=43)		Over-reporters (n=7)			
	Mean	SEM	Mean	SEM	Mean	SEM	*P value* [1]	*P value* [2]
BWT (g)	3478	82	3632	82	3628	224	*0.509*	*0.948*

P value [1] – one-way ANOVA
P value [2] – adjusted for age, parity, ethnicity and DEPCAT status, baby gender, duration of gestation and maternal height

Table 7.4d

Mean (standard error mean, SEM) of birth weight (BWT) according to energy intake reporting accuracy status in lean group

	Under-reporters (n=9)		Adequate reporters (n=47)		Over-reporters (n=9)			
	Mean	SEM	Mean	SEM	Mean	SEM	*P value* [1]	*P value* [2]
BWT (g)	3356	129	3492	65	4072	196	*0.002*	*0.162*

P value [1] – one-way ANOVA
P value [2] – adjusted for age, parity, ethnicity and DEPCAT status, baby gender, duration of gestation and maternal height

Table 7.5a

Pearson correlation coefficients *(r)* between gestational weight gain* and maternal reported food intake (completed at 28-weeks gestation) in a subgroup whose reporting accuracy was assessed

Nutrient	Obese (n=98)			Lean (n=68)		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
Energy (kcal)	0.164	*0.107*	*0.575*	0.224	*0.066*	*0.781*
Protein (g)	-0.079	*0.440*	*0.251*	0.056	*0.652*	*0.806*
Fat (g)	-0.094	*0.356*	*0.703*	0.298	*0.014*	*0.035*
Carbohydrate (g)	0.117	*0.252*	*0.366*	-0.275	*0.023*	*0.062*
SFA (g)	-0.178	*0.079*	*0.207*	0.227	*0.062*	*0.262*
MUFA (g)	-0.136	*0.182*	*0.432*	0.207	*0.061*	*0.016*
PUFA (g)	0.103	*0.314*	*0.346*	0.137	*0.265*	*0.120*
Cholesterol (mg)	-0.193	*0.057*	*0.097*	0.198	*0.105*	*0.282*
Sugars (g)	0.094	*0.358*	*0.405*	-0.231	*0.059*	*0.107*
Starch (g)	0.034	*0.740*	*0.809*	-0.054	*0.660*	*0.877*
Fibre (g)	0.202	*0.046*	*0.198*	-0.163	*0.185*	*0.292*
Sodium (mg)	0.032	*0.758*	*0.496*	-0.003	*0.981*	*0.851*
Potassium (mg)	0.083	*0.419*	*0.908*	-0.279	*0.051*	*0.059*
Calcium (mg)	-0.102	*0.315*	*0.079*	-0.232	*0.057*	*0.062*
Magnesium (mg)	0.137	*0.179*	*0.466*	-0.153	*0.214*	*0.266*
Phosphorus (mg)	-0.166	*0.103*	*0.070*	-0.155	*0.207*	*0.090*
Iron (mg)	0.185	*0.069*	*0.611*	-0.067	*0.586*	*0.056*
Copper (mg)	0.100	*0.328*	*0.379*	0.148	*0.229*	*0.644*
Zinc (mg)	-0.051	*0.616*	*0.487*	0.150	*0.222*	*0.487*
Chloride (mg)	-0.013	*0.899*	*0.907*	0.029	*0.811*	*0.969*
Manganese (mg)	0.116	*0.255*	*0.436*	-0.104	*0.399*	*0.400*
Selenium (µg)	0.051	*0.615*	*0.973*	-0.036	*0.772*	*0.793*
Iodine (µg)	-0.111	*0.277*	*0.088*	-0.138	*0.262*	*0.232*
Retinol (µg)	-0.086	*0.398*	*0.664*	0.124	*0.313*	*0.760*
B-carotene equ (µg)	0.214	*0.034*	*0.048*	0.062	*0.617*	*0.659*
Vitamin D (µg)	0.085	*0.406*	*0.303*	0.122	*0.322*	*0.206*
Vitamin E (mg)	0.093	*0.362*	*0.783*	-0.021	*0.865*	*0.440*
Thiamine (mg)	0.024	*0.812*	*0.924*	-0.169	*0.169*	*0.098*
Riboflavin (mg)	-0.144	*0.157*	*0.072*	-0.215	*0.079*	*0.028*
Niacin (mg)	0.084	*0.410*	*0.551*	0.069	*0.576*	*0.602*
Potential niacin (mg)	-0.107	*0.296*	*0.253*	0.187	*0.126*	*0.386*
Vitamin B6 (mg)	0.152	*0.136*	*0.287*	-0.017	*0.889*	*0.742*
Vitamin B12 (µg)	-0.071	*0.485*	*0.543*	0.033	*0.791*	*0.815*
Folic acid (µg)	0.056	*0.585*	*0.883*	-0.154	*0.210*	*0.304*
Pantothenic acid (mg)	-0.111	*0.278*	*0.168*	-0.037	*0.767*	*0.590*
Biotin (µg)	-0.080	*0.434*	*0.272*	-0.098	*0.427*	*0.488*
Vitamin C (mg)	0.144	*0.158*	*0.431*	-0.050	*0.684*	*0.806*
Vitamin K (µg)	0.100	*0.329*	*0.284*	0.122	*0.322*	*0.484*
Alcohol	-0.077	*0.451*	*0.504*	-0.128	*0.299*	*0.255*

* Calculated as the difference between weight at first visit and 36-weeks visit
P value [1] – log-transformed data, adjusted for energy intake
P value [2] – log-transformed data, adjusted for energy intake, reporting accuracy, age, parity, ethnicity, DEPCAT status, baby gender, duration of gestation and maternal height

Table 7.5b

Pearson correlation coefficients *(r)* between birth weight and maternal reported food intake (completed at 28-weeks gestation) in a subgroup whose reporting accuracy was assessed

Nutrient	Obese (n=97)			Lean (n=65)		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
Energy (kcal)	0.087	*0.412*	*0.855*	0.422	*<0.001*	*0.001*
Protein (g)	0.177	*0.092*	*0.062*	0.138	*0.272*	*0.368*
Fat (g)	0.092	*0.381*	*0.834*	0.139	*0.268*	*0.439*
Carbohydrate (g)	0.165	*0.117*	*0.603*	-0.173	*0.169*	*0.346*
SFA (g)	0.119	*0.244*	*0.936*	0.071	*0.574*	*0.446*
MUFA (g)	0.125	*0.221*	*0.649*	0.126	*0.359*	*0.546*
PUFA (g)	0.042	*0.784*	*0.802*	0.267	*0.048*	*0.270*
Cholesterol (mg)	-0.140	*0.172*	*0.432*	0.138	*0.271*	*0.676*
Sugars (g)	-0.127	*0.217*	*0.245*	-0.338	*0.006*	*0.009*
Starch (g)	0.007	*0.944*	*0.478*	0.228	*0.068*	*0.041*
Fibre (g)	0.074	*0.484*	*0.402*	0.006	*0.961*	*0.627*
Sodium (mg)	-0.040	*0.705*	*0.978*	0.116	*0.399*	*0.700*
Potassium (mg)	0.050	*0.634*	*0.686*	-0.076	*0.582*	*0.625*
Calcium (mg)	-0.007	*0.948*	*0.444*	-0.065	*0.637*	*0.386*
Magnesium (mg)	-0.070	*0.509*	*0.258*	0.170	*0.214*	*0.108*
Phosphorus (mg)	-0.085	*0.419*	*0.161*	0.133	*0.332*	*0.616*
Iron (mg)	0.020	*0.850*	*0.242*	0.109	*0.387*	*0.016*
Copper (mg)	0.120	*0.253*	*0.913*	0.151	*0.272*	*0.141*
Zinc (mg)	-0.095	*0.367*	*0.199*	0.319	*0.018*	*0.021*
Chloride (mg)	0.073	*0.491*	*0.715*	0.137	*0.320*	*0.726*
Manganese (mg)	0.047	*0.659*	*0.236*	0.234	*0.086*	*0.340*
Selenium (µg)	-0.131	*0.212*	*0.098*	-0.061	*0.657*	*0.884*
Iodine (µg)	0.053	*0.615*	*0.275*	-0.082	*0.553*	*0.221*
Retinol (µg)	0.050	*0.633*	*0.260*	0.125	*0.365*	*0.899*
B-carotene equ (µg)	-0.147	*0.163*	*0.128*	0.062	*0.651*	*0.810*
Vitamin D (µg)	0.116	*0.260*	*0.543*	0.045	*0.744*	*0.880*
Vitamin E (mg)	0.039	*0.712*	*0.976*	0.040	*0.773*	*0.979*
Thiamine (mg)	-0.105	*0.319*	*0.120*	0.261	*0.054*	*0.019*
Riboflavin (mg)	0.090	*0.394*	*0.133*	0.073	*0.596*	*0.671*
Niacin (mg)	0.204	*0.051*	*0.060*	0.073	*0.195*	*0.099*
Potential niacin (mg)	0.125	*0.236*	*0.150*	0.178	*0.194*	*0.527*
Vitamin B6 (mg)	0.097	*0.357*	*0.269*	0.056	*0.686*	*0.362*
Vitamin B12 (µg)	0.122	*0.247*	*0.325*	-0.058	*0.675*	*0.310*
Folic acid (µg)	0.049	*0.636*	*0.145*	0.196	*0.118*	*0.238*
Pantothenic acid (mg)	0.127	*0.229*	*0.063*	0.117	*0.396*	*0.715*
Biotin (µg)	0.106	*0.313*	*0.082*	0.185	*0.176*	*0.258*
Vitamin C (mg)	0.098	*0.353*	*0.868*	-0.119	*0.385*	*0.514*
Vitamin K (µg)	-0.047	*0.658*	*0.286*	0.226	*0.097*	*0.421*
Alcohol	0.138	*0.190*	*0.392*	-0.016	*0.906*	*0.464*

P value [1] – log-transformed data, adjusted for energy intake
P value [2] – log-transformed data, adjusted for energy intake, reporting accuracy, age, parity, ethnicity, DEPCAT status, baby gender, duration of gestation and maternal height

Table 7.6a demonstrates that weight gain during pregnancy increased with higher general nutrition knowledge scores in the obese group, and a similar pattern was seen across the GWG adequacy categories (Figure 7.4). There was an inverse association between GWG and general nutrition knowledge in lean but this was no longer significant after adjustment for possible confounding factors (Table 7.6a). There was a trend in the obese group for increased GWG with greater appetite in late pregnancy (Table 7.6b) and this was found to be significant when appetite score was assessed according to GWG adequacy status (Figure 7.5). No association was observed in the lean group. A positive association was observed between restraint eating behaviour mean score and GWG in obese, but not in lean (Table 7.6c). No associations between BWT and scores of general nutrition knowledge, appetite, and eating behaviours, were observed in either obese or lean (Tables 7.7a, 7.7b, and 7.7c).

Table 7.6a

Pearson correlation coefficients *(r)* between gestational weight gain* and general nutrition knowledge (GNK) scores

	Obese (n=66)			Lean (n=51)		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
GNK score	0.223	*0.072*	0.043	-0.260	*0.055*	*0.084*

* Calculated as the difference between weight at first visit and 36-weeks visit
P value [1] – Unadjusted data
P value [2] – Data adjusted for age, parity, ethnicity, DEPCAT, marital status and education level

Table 7.6b

Pearson correlation coefficients *(r)* between gestational weight gain* and reported appetite (early and late pregnancy)

	Obese			Lean		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
Early Pregnancy:	(n=58)			(n=40)		
Appetite score	0.069	*0.604*	*0.962*	-0.247	*0.125*	*0.126*
Late Pregnancy:	(n=57)			(n=41)		
Appetite score	0.257	*0.053*	*0.048*	0.023	*0.886*	*0.941*

* Calculated as the difference between weight at first visit and 36-weeks visit
P value [1] – Unadjusted data
P value [2] – Data adjusted for age, parity, ethnicity, and DEPCAT status

Figure 7.4

General nutrition knowledge score according to gestational weight gain status in obese group (n=66)

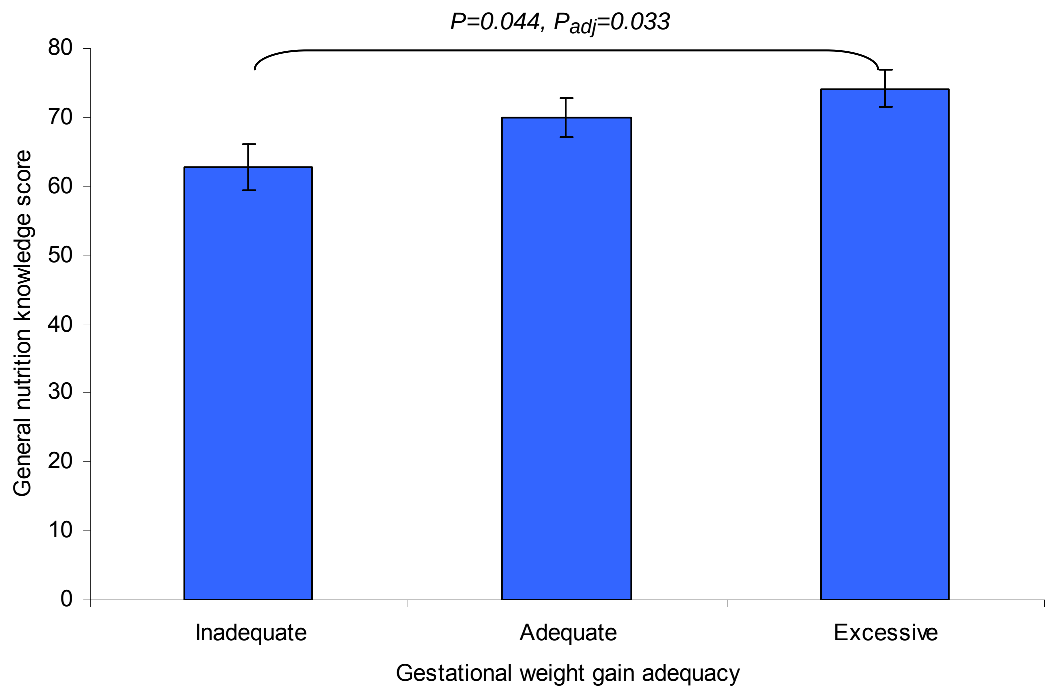


Figure 7.5

Appetite score in late pregnancy according to gestational weight gain status in obese group (n=57)

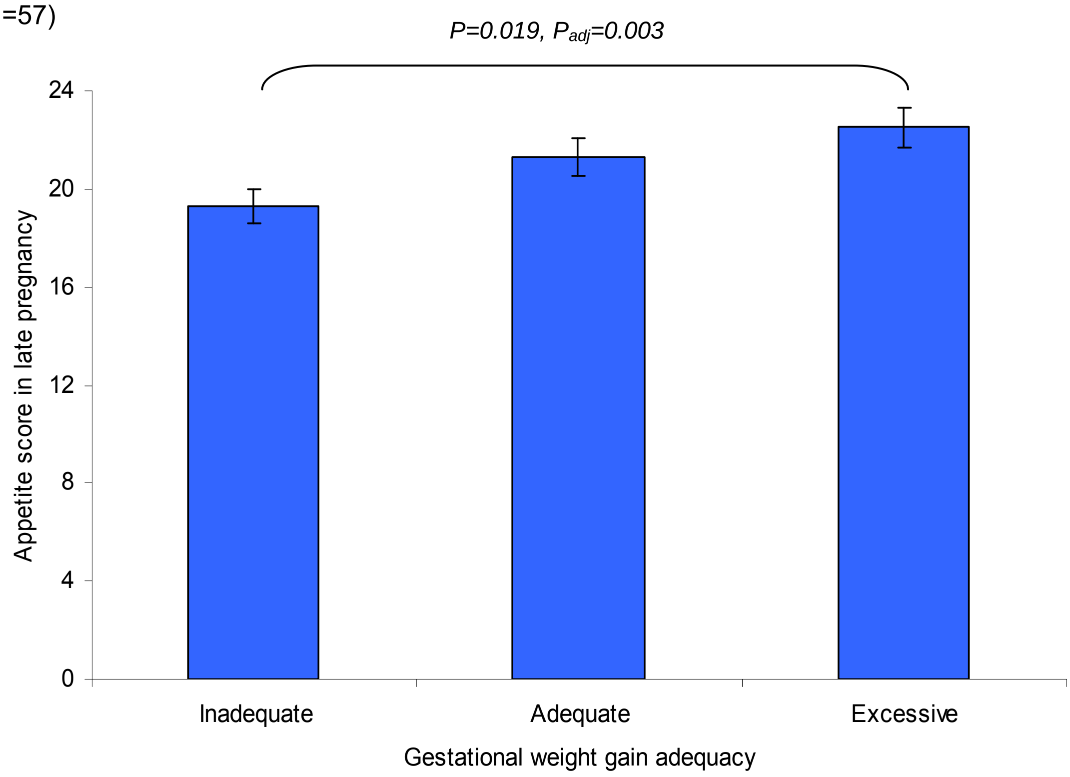


Table 7.6c

Pearson correlation coefficients *(r)* between gestational weight gain* and mean scores of reported eating behaviour

	Obese (n=48)			Lean (n=37)		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
Restraint eating	0.296	*0.041*	*0.047*	0.056	*0.741*	*0.853*
Emotional eating	0.136	*0.356*	*0.796*	0.268	*0.109*	*0.073*
Externally cued eating	0.243	*0.096*	*0.265*	0.050	*0.725*	*0.434*

* Calculated as the difference between weight at first visit and 36-weeks visit
P value [1] – Unadjusted data
P value [2] – Data adjusted for age, parity, ethnicity, and DEPCAT status

Table 7.7a

Pearson correlation coefficients *(r)* between birth weight and maternal general nutrition knowledge (GNK) scores

	Obese (n=67)			Lean (n=48)		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
GNK score	0.172	*0.164*	*0.171*	0.103	*0.448*	*0.570*

P value [1] – Unadjusted data
P value [2] – Data adjusted for age, parity, ethnicity, DEPCAT, marital status and education level

Table 7.7b

Pearson correlation coefficients *(r)* between birth weight and maternal reported appetite (early and late pregnancy)

	Obese			Lean		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
Early Pregnancy:	(n=49)			(n= 32)		
Appetite score	-0.158	*0.279*	*0.196*	0.253	*0.163*	*0.186*
Late Pregnancy:	(n=52)			(n=40)		
Appetite score	0.030	*0.835*	*0.664*	-0.015	*0.926*	*0.712*

P value [1] – Unadjusted data
P value [2] – Data adjusted for age, parity, ethnicity, DEPCAT status, baby gender, duration of gestation and maternal height

Table 7.7c

Pearson correlation coefficients *(r)* between birth weight and mean scores of reported eating behaviour

	Obese (n=40)			Lean (n=28)		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
Restraint eating	-0.136	*0.402*	*0.431*	-0.139	*0.479*	*0.562*
Emotional eating	0.121	*0.457*	*0.848*	0.078	*0.695*	*0.994*
Externally cued eating	-0.120	*0.462*	*0.357*	0.304	*0.116*	*0.490*

P value [1] – Unadjusted data
P value [2] – Data adjusted for age, parity, ethnicity, DEPCAT status, baby gender, duration of gestation and maternal height

GWG was not associated with reported PA in either group (Table 7.8a). BWT was not associated with reported PA in obese (Table 7.8b). In lean, BWT was positively correlated with total activity (r=0.238, $P_{adj}=0.046$). This also included a positive association of BWT with moderate-intensity activity, although the significance did not persist after adjustment for confounders. There was also a trend for BWT to be inversely associated with sedentary activity during both early and late pregnancy but this did not reach statistical significance.

Table 7.8a

Pearson correlation coefficients *(r)* between gestational weight gain* and reported physical activity (early and late pregnancy)

Reported physical activity (MET-hours/week)	Obese			Lean		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
Early Pregnancy:	(n= 124)			(n=77)		
Total activity	-0.163	*0.070*	*0.305*	-0.021	*0.862*	*0.616*
Sedentary	0.052	*0.566*	*0.982*	-0.004	*0.866*	*0.304*
Light	-0.114	*0.206*	*0.898*	0.137	*0.216*	*0.069*
Moderate	-0.117	*0.195*	*0.460*	-0.105	*0.403*	*0.887*
Vigorous	-0.019	*0.833*	*0.956*	-0.110	*0.309*	*0.527*
Household/caregiving	-0.153	*0.090*	*0.533*	0.009	*0.738*	*0.224*
Occupational	0.001	*0.989*	*0.279*	0.139	*0.528*	*0.618*
Sports and exercise	0.055	*0.547*	*0.679*	0.038	*0.649*	*0.849*
Late Pregnancy:	(n= 92)			(n=51)		
Total activity	-0.099	*0.352*	*0.634*	-0.188	*0.187*	*0.743*
Sedentary	0.018	*0.864*	*0.864*	0.139	*0.330*	*0.670*
Light	-0.088	*0.405*	*0.317*	-0.015	*0.915*	*0.316*
Moderate	-0.113	*0.286*	*0.761*	-0.220	*0.121*	*0.430*
Vigorous	-0.135	*0.202*	*0.200*	-0.027	*0.850*	*0.953*
Household/caregiving	-0.164	*0.120*	*0.695*	-0.144	*0.312*	*0.809*
Occupational	-0.022	*0.839*	*0.293*	0.208	*0.143*	*0.297*
Sports and exercise	0.020	*0.848*	*0.629*	-0.041	*0.773*	*0.537*

* Calculated as the difference between weight at first visit and 36-weeks visit
P value [1] – log-transformed data, unadjusted
P value [2] – log-transformed data, adjusted for age, parity, ethnicity, DEPCAT, and working status

Table 7.8b

Pearson correlation coefficients *(r)* between birth weight and maternal reported physical activity (early and late pregnancy)

Reported physical activity (MET-hours/week)	Obese			Lean		
	r	*P value*[1]	*P value*[2]	*r*	*P value*[1]	*P value*[2]
Early Pregnancy:	(n= 119)			(n=69)		
Total activity	0.012	*0.896*	*0.919*	0.238	*0.049*	*0.046*
Sedentary	-0.038	*0.679*	*0.942*	-0.232	*0.055*	*0.177*
Light	-0.068	*0.487*	*0.374*	0.161	*0.187*	*0.124*
Moderate	0.069	*0.458*	*0.693*	0.241	*0.046*	*0.067*
Vigorous	0.086	*0.420*	*0.132*	0.199	*0.101*	*0.495*
Household/caregiving	-0.033	*0.723*	*0.509*	0.096	*0.432*	*0.173*
Occupational	-0.003	*0.978*	*0.313*	-0.092	*0.454*	*0.193*
Sports and exercise	0.178	*0.053*	*0.221*	0.025	*0.841*	*0.834*
Late Pregnancy:	(n=90)			(n=50)		
Total activity	-0.039	*0.734*	*0.931*	0.015	*0.920*	*0.397*
Sedentary	-0.106	*0.322*	*0.212*	-0.220	*0.124*	*0.197*
Light	0.017	*0.880*	*0.485*	0.051	*0.723*	*0.919*
Moderate	-0.013	*0.901*	*0.845*	0.083	*0.569*	*0.337*
Vigorous	0.004	*0.967*	*0.514*	0.080	*0.583*	*0.171*
Household/caregiving	0.054	*0.613*	*0.295*	-0.039	*0.788*	*0.916*
Occupational	-0.022	*0.840*	*0.130*	-0.001	*0.994*	*0.622*
Sports and exercise	0.191	*0.065*	*0.380*	-0.046	*0.751*	*0.161*

P value [1] – log-transformed data, unadjusted
P value [2] – log-transformed data, adjusted for age, parity, ethnicity, DEPCAT, and working status

7.5 Discussion

This study aimed to examine the associations between total GWG and BWT, with both maternal self-reported diets and PA among lean and severely obese pregnant women, including in a subgroup of study participants in whom data for energy reporting accuracy were available.

In this study, a positive association between GWG and BWT was observed in lean women, as has been previously reported (Lagiou et al, 2004, Shapiro, Sutija and Bush, 2000). No correlation was evident with respect to the obese group. Others have demonstrated a positive association between increased maternal BMI and increased fetal growth, which seemed to plateau at the highest levels of maternal BMI (HAPO Study Cooperative Research Group, 2010). In this observational cohort study involving 23,316 women, increased frequency of BWT >90th percentile was associated with increasing BMI, except in the two highest categories (BMI class II and III) (HAPO Study Cooperative Research Group, 2010). It was suggested that this could either be due to the presence of a maximal effect of increasing BMI on increasing BWT before the BMI category reached this level, or that this apparent plateau effect was influenced by other factors that limit fetal growth such as the increased incidence of preeclampsia in these highest BMI groups (HAPO Study Cooperative Research Group, 2010). In another study in 385 obese (BMI ≥30) women, a U-shaped distribution was observed between maternal booking BMI and BWT, with high rates of SGA (18.8%) and LGA (13.4%) deliveries (Rajasingam et al, 2009). The lack of a positive association between BMI and BWT was thought to be due to the high incidence of SGA in their study population. Indeed, >50% of SGA was determined to be unrelated to preeclampsia suggesting that other factors limiting growth such maternal physical constraint associated with nulliparity (Rajasingam et al, 2009) may have a role to play. In the current study, BWT was adjusted for factors which might influence maternal physical constraint such as parity and mother's height, however both of these were not significantly different in the regression model (e.g. parity, *P=0.89* and maternal height, *P=0.102* for obese group).

The IOM (Rasmussen and Yaktine, 2009) recently revised their guidelines for healthy GWG and advised a weight gain of between 5 to 9kg for obese women (with BMI>30.0 kg/m^2). However, there are no recommendations for specific obesity classes, particularly for women with BMI>40.0 kg/m^2. In our study, obese women were found to gain only about half as much weight as the lean controls, although the range was quite large (-10.0 to 21.7kg). A similar pattern has been reported by others (Centre for Maternal and Child Enquiries, 2010, Rasmussen and Yaktine, 2009, Chu et al, 2009, Nohr et al, 2008). All obese women in the current study received tailored dietary advice from a specialized dietitian as part of the routine antenatal care provided at the Antenatal Metabolic Clinic, and this may have influenced the lower GWG in this group. However, a recent study found no significant difference in the percentage of obese (BMI>30) women who adhered to IOM recommendations for GWG after receiving intensive counselling regarding diet and lifestyle, compared to a control group who received only routine antenatal care and standard diet and exercise information only (33.3% vs 20.0%, *P=NS*) (Asbee et al, 2009). Obese women in the current study were also weighed at each clinic visit and this could be another factor that have made them more conscious about their GWG. An intervention study which focused on the effect of regular weight measurement throughout pregnancy on GWG, however, found that although significant weight reduction occurred in participants in the overweight (BMI 26-29) category (GWG rate: intervention group, 0.42kg/week vs control group, 0.54kg/week, *P=0.01*), no significant difference was observed in the obese (BMI>30) category (Jeffries et al, 2009).

Despite the lower GWG, it was found that more of the obese women met (37% vs 34%) or exceeded (21% vs 10%) the IOM recommended guidelines, than lean, despite the fact that GWG was only measured between booking and 36-weeks in the current study, as opposed to between booking and 40 weeks in the IOM guidelines. A large population-based cohort study reported that a weight gain of <6.7kg among severely obese women (BMI>40 kg/m^2) was associated with a reduction in the risk of adverse outcomes such as BWT ≥4000g and neonatal metabolic abnormalities (Crane et al, 2009). The rate of adverse outcomes (caesarean section, gestational hypertension, 2500g< BWT ≥ 4000g) was lower in obese women (BMI ≥30) with GWG within IOM recommendations (5-9kg) as opposed to in those with excess weight gain (Hinkle, Sharma and Dietz, 2010). This study, involving 122,327 women, also found that adverse outcomes were reduced in class II and III obese women who had gained weight below the IOM guidelines (between -4.9 to 4.9kg) and this was associated with less use of epidural analgesia during delivery. In these women, low GWG also decreased the odds of macrosomia (BWT ≥ 4500g), and additionally, it was not associated with incidence of SGA births (Hinkle, Sharma and Dietz, 2010). However, not all studies fully support the beneficial outcomes of meeting the IOM recommendations. In another study including 678,560 singleton deliveries, it was found that overweight and obese mothers who gained weight between 5-9kg had less incidence of preeclampsia and non-elective caesarean deliveries, but at the same time, also had higher risks of gestational diabetes, SGA births, preterm delivery and perinatal mortality (Beyerlein, Lack, and von Kries, 2010). However, all of these studies were based on retrospective register analysis and so may be more subject to errors due to confounding and bias, as compared to prospectively designed studies.

In the present study, GWG in obese was positively associated with increasing intake of total carbohydrate during late pregnancy, and dietary cholesterol throughout pregnancy. In lean, GWG was positively correlated with total energy and total fat intakes (including SFA and MUFA) but inversely associated with intakes of total carbohydrate during early and late pregnancy. Only the positive association with total fats in the lean group remained significant after adjustment for reporting accuracy. In a study of 224 pregnant women, Lagiou et al (2004) also found that maternal weight gain was significantly positively associated with energy intake as well as energy-adjusted intake of protein and animal fats, but was inversely associated with intakes of total carbohydrate. They, however, only included weight gain until the end of second trimester (27th week of gestation), and so underestimated total GWG, as weight changes during 3rd trimester may be substantial. A recent systematic review which included 12 studies assessing dietary intake during pregnancy and GWG outcomes, found that significant positive associations between GWG and total energy and protein intake were reported by 7 different studies (Streuling et al, 2011). The studies included in this systematic review varied considerably with respect to dietary assessment and definition of GWG, and only a fraction of them adjusted their published results for potential confounding factors such as maternal age, parity, and socioeconomic status. Olafsdottir et al (2006) reported that overweight women with excessive GWG consumed total calories which were proportionally higher in fat and lower in carbohydrate.

In the current study, a positive correlation between BWT and total energy during late pregnancy was seen in lean, and this effect remained after controlling for energy misreporting status. Maternal caloric intake during late pregnancy may have a more profound effect on BWT compared to intake in early pregnancy as demonstrated by the follow-up studies of babies in utero during the Dutch Winter Hunger famine in 1944-45 (reviewed by Schulz, 2010). It was reported that infants of mothers who were exposed to the famine during early pregnancy delivered infants with normal BWT. On the other hand, mothers who experienced the famine during late pregnancy had babies with reduced BWT (Schulz, 2010). This was probably because substantial fetal growth and development occurs in late pregnancy and the fetus gains weight very quickly from the eighth month of pregnancy and onwards (American College of Obstetricians and Gynecologists, 2010). In addition to the association of BWT with total energy intake in late pregnancy, BWT was also positively associated with starch intake, but inversely associated with sugar intake in late pregnancy in lean group. These findings remained significant after adjustment for reporting accuracy. Likewise, Godfrey et al (1996) reported a negative association between total carbohydrate intake and infants' thinness at birth in a general pregnant women population. A similar trend between total carbohydrate intake and BWT was seen in our lean group, however this did not reach significance. These associations are in contrast to findings of other studies investigating the effect of diets comprising different types of carbohydrates (high/low glycemic index (GI)) during pregnancy on birth outcomes. For example, it was demonstrated that a high GI diet (which was approximately equivalent to high sugar intakes in the current study) was significantly associated with higher BWT, as well as higher prevalence of LGA, and in contrast, a low GI diet was associated with reduced BWT (Moses et al, 2006, Scholl et al, 2004). It can only be speculated that in the current study, since the lean women were highly educated and of high socioeconomic status, they were also conscious about their health and food intake during pregnancy. In their effort to eat more healthily, they reduced their sugary foods intake but in compensation they increased the intake of starchy foods, and this was reflected in the association between these nutrients and BWT of their babies.

In nutritional studies, associations between total energy and/or specific nutrient intakes and certain outcome parameters are often used to explore disease risk. However, because intakes of most nutrients, especially macronutrients, are correlated with energy intake, they may be confounded by energy intake and thus be non-causally associated with disease risks. Therefore, adjustment of nutrients for energy intake such as by using the nutrient density or residual method, is necessary to reduce this confounding effect (Willet, Howe and Kushi, 1997). Prevalence of measurement errors, particularly in energy reporting, may also attenuate correlations between nutrients and measured outcomes, weakening potential true associations between diet and disease. In this study, it was found that total energy intake (in lean) and macro- and micronutrients (in both obese and lean) were associated with GWG and BWT in the study population. However, most of these effects were not seen in the subgroup whose results were controlled for misreporting accuracy, albeit in a smaller sample size. This suggests that reporting accuracy of energy intake is important in determining the true roles that nutrients play in the development of disease. Interestingly, in the lean group, GWG (and BWT) were significantly increased with degree of reporting accuracy, and this was not seen in the obese group. One possible explanation for this is that the under-reporting of food intake in lean subjects was not simply caused by under-recording (which might be the case in the obese group), but also due to genuine under-eating, which led to the reduced GWG (and hence lower BWT) seen in this group of women.

Health benefits of PA during pregnancy for both mother and baby are increasingly being recognized. The American College of Obstetricians and Gynaecologists recommended that healthy pregnant women should take up 30 minutes of at least moderate intensity activities for most, if not all, days of the week (Artal and O'Toole, 2003). Regular exercise has been positively associated with low or reduced risk for excessive GWG (Owe, Nystad and Bo, 2009, Stuebe et al, 2009). However, in a systematic review of clinical trials assessing the effects of PA on weight gain during pregnancy in overweight and obese women, few studies confirmed the positive effect of exercise on managing weight gain in this group (Nascimento et al, 2011a). This lack of association between PA and GWG was also found in both our obese and lean groups. No association was observed between PA energy expenditure and BWT in obese. In lean, on the other hand, BWT was positively associated with reported total PA during early pregnancy. The findings of studies examining the association between PA and BWT have been inconsistent and no studies have specifically looked at a severely obese group. Studies in general pregnant women populations have reported that regular exercise may lead to smaller BWT (Hopkins et al, 2010) or increase the risk of low BWT (Perkins et al, 2007), or that exercise has a protective effect against excessive BWT (Owe, Nystad and Bo, 2009, Clapp et al, 2000). One study found that BWT was decreased with increasing exercise, but this association was weakened when maternal pre-pregnancy BMI was taken into account (Fleten et al, 2010). There seems to be a consensus, however, that mild-to moderate intensity exercise is safe during pregnancy for general (Takito and Benicio, 2010, Schlussel et al, 2008), as well as, overweight and obese (Nascimento et al, 2011b) women, and so should be continued, but excessive and vigorous activities should be avoided (Takito, Benicio and Neri, 2009, Schlussel et al, 2008, Morris and Johnson, 2005).

Surprisingly the general nutrition knowledge score was positively associated with GWG in obese, with a trend for an inverse association in lean. No association was observed between nutrition knowledge and BWT in either group. The connection between general nutrition knowledge and weight gain during pregnancy has not been studied previously. The only available studies have focused on associations between GWG and specific knowledge such as current weight gain recommendations (Tovar et al, 2010) or weight gain advice received from health providers (Stotland et al, 2005, Cogswell et al, 1999). The fact that the obese group showed a tendency to increase GWG with greater nutrition knowledge is of concern and requires further investigation as this may influence the outcome of interventions on GWG management in this population. Reported scores of appetite, emotional eating, and externally- cued eating, were not correlated with either GWG or BWT in this study. Restraint behaviour score, however, was found to be positively associated with GWG in the obese group. A pre-pregnancy history of restraint behaviour and dieting has been associated with, increased weight gain in women from all BMI classes (except underweight women) during pregnancy as reported in a study of 1,223 pregnant women (Mumford et al, 2008). In addition, a greater proportion of subjects with restrained behaviour history were found to have adequate GWG (based on the 1990 IOM recommendations) compared to those without (Mumford et, 2008). Restrained eating refers to the deliberate restriction of dietary intake in an attempt to control body weight and has been associated with reduced energy intake in non-pregnant women (Anschutz et al, 2009). However pregnancy has been suggested to promote disinhibition in restrained eaters by relaxing restrictive diets as well as legitimising an increased food intake (Clark and Ogden, 1999).

The strength of this study is in its prospective cohort design including severely obese pregnant women and lean controls. However, there are several limitations. Firstly, no accurately recorded pre-pregnancy weight data was available and thus GWG was measured as the difference in weight between the first visit (between 12-20 weeks) and the 36-weeks visit. However, as not all women monitor their weight before becoming pregnant, any self-reported pre-pregnancy weight would be of questionable accuracy. Secondly, the assessment of energy intake reporting accuracy was not possible in the whole study group. The subgroup with misreporting information made up at least three quarter of obese group and almost all of lean group. A number of obese women were not included in the misreporting study due to not fulfilling requirements such as presenting for the first visit before 20 weeks gestation and completing both food frequency and PA questionnaires at 28 weeks visit (discussed in detail in Chapter 5). Thirdly, the extent to which the ‘intervention’ of obese women being seen by a specialised dietitian and weighed at each clinic attendance influenced the results is not known.

In conclusion, in the severely obese women in this study, GWG was not influenced by diet or PA but was associated with increasing level of general nutrition knowledge and higher scores of restraint eating behaviour. BWT in this group was also not associated with dietary intake, PA, or any of the other factors assessed. These findings differ from observations in lean pregnant women, and if replicated in other studies, may inform future intervention studies on how to modify GWG and BWT in this population.

CHAPTER 8

Assessment of total energy expenditure and self-reporting accuracy using doubly labelled water technique: A pilot study

Chapter 8

8.1 Introduction

Energy requirements during pregnancy have been a matter of much debate. It is generally expected that the overall requirements of energy are elevated due to the increase in basal metabolic rate and pregnancy energetic cost of synthesizing fetoplacental tissue and retention of fat and protein in the mother (Lof and Forsum, 2006). However, the magnitude of increase is still to be determined due to uncertainties regarding optimal amount of maternal fat deposition and changes in the costs and volume of physical activity (PA) in pregnancy (Byrne et al, 2011). The results of Chapter 6 showed no statistical difference between self-reported PA between obese and lean women, both during early and late pregnancy. However, this was not supported by the objective measurement which showed lower accelerometry activity measures in obese as compared to lean. Self-reported information may not be reliable in providing information regarding energy expenditure in this study population. A technique which could provide quantitative measurement such as the doubly labelled water (DLW) may therefore be more insightful.

The DLW is considered the gold standard technique in measuring the daily total energy expenditure (TEE) in humans (Schoeller and van Santen, 1982). Since its first use in human studies in the 1980s, the DLW method has been widely used to assess TEE for different populations, to study the aetiology of obesity and to validate dietary assessment tools (Schoeller, 1999). It also allowed gestational energy requirements (based on TEE) to be quantified (Butte et al, 2004, Kopp-Hoolihan et al, 1999, Goldberg et al, 1993, Forsum et al, 1992). Most of these studies were carried out in normal weight pregnant women. Recently, energy requirements were estimated in 63 underweight, normal weight, and overweight (BMI $\geq$ 26) pregnant women which indicated energy requirements to generally increase throughout pregnancy, but the magnitude differed according to pre-pregnancy BMI with the overweight group having the least increment of TEE (Butte et al, 2004).

The effect of severe obesity on energy requirements in pregnancy is not known. The use of the DLW technique not only would enable this to be quantified, but also would provide an additional mean to assess reporting accuracy of total energy intake and to determine whether the high prevalence of under-reporting among obese women (as discussed earlier in Chapter 5) could be confirmed. DLW could also be used to evaluate the accuracy of self-reported PA (presented in Chapter 6) in this study population. These reasons necessitated the DLW assessments in this population, and this was carried out in a pilot study.

8.2 Aim(s)

The aims of this chapter were to:

a) measure TEE (and total energy requirement) objectively

b) assess the validity of reported food intake and total PA by comparing it to the measured TEE

in a subgroup of obese pregnant women who were enrolled in Energy Balance in Pregnancy (EBIP) study at the Antenatal Metabolic Clinic.

8.3 Methods

8.3.1 Study design

This is an observation as well as a validation study. Participants for the Energy Balance in Pregnancy (EBIP) Study were recruited among the volunteers of the Hormones and Inflammation in Pregnancy (HIP) study at the Antenatal Metabolic Clinic from July until November 2010.

8.3.2 Ethical approval

The study was approved by the Lothian NHS Research Ethics Committee and all subjects gave written informed consent.

8.3.3 Subjects recruitment

The severely obese pregnant women who were enrolled in the HIP Study and had indicated that they would be interested in volunteering for other more detailed studies within the Antenatal Metabolic Clinic were invited to take part in this component of the EBIP study.

A subgroup of 14 subjects was invited to take part in this study. 7 declined to participate in the study: 4 due to concern about the safety of the protocol in short and long-term particularly on their babies, 2 due to work commitment, and 1 changed her mind just before the study started (no reason was given). 1 subject agreed but could not be included due to multiple health problems. Available data was provided by 6 subjects.

8.3.4 Measurement of fat-free mass

Total body fat-free mass (kilograms) was measured by using body composition analyzer Tanita TBF-300M (Tanita UK Limited, Middlesex, UK) as explained in detail in Section 2.4.3.

8.3.5 Principles of doubly-labelled water

The DLW method involves the administration of a dose of water containing labelled hydrogen (deuterium, ^{2}H) and oxygen ($^{18}0$). These stable isotopes replace the regular hydrogen and oxygen in the water in enriched amounts so that they can act as tracers, as discussed in detail in Section 2.6.3.

8.3.6 Dosing protocol

After fasting overnight, subjects were asked to attend the clinic in the morning for the dosing. After a baseline urine sample was collected and body weight measured, each subject was given the DLW dose (120ml) to drink until finished. Subjects were then asked to collect one urine sample on day 1, day 5, day 10 and day 14 (as detailed in Section 2.6.3).

8.3.7 Sample Analysis

Analysis was carried out by Energetics Group, Zoology Department, University of Aberdeen, UK by using isotope ratio mass spectrometry (as detailed in Section 2.7.8).

8.3.8 Statistical Analysis

Due to small number of subjects, there was not enough power for formal statistical analysis to assess the difference of mean TEE between early and late pregnancy. However, possible associations between TEE obtained from DLW, and total energy intake as reported in Scottish Collaborative Group Food Frequency Questionnaire as well as total PA as reported in Pregnancy Physical Activity Questionnaire were explored by using Spearman correlation coefficients.

8.4 Results

This pilot study was conducted in 6 severely obese pregnant subjects. Two subjects (Subject 1/5 and Subject 2/6) completed the DLW both during early and late pregnancy, therefore data were available for 4 subjects each in early and late pregnancy. Their demographic characteristics are presented in Table 8.1. Mean gestation for early pregnancy was 21.8 weeks (SD 2.1) and 31.3 (SD 1.9) weeks for late pregnancy. Mean weight was 116.1 and 113.7kg (SD 7.3, 5.7) for early and late pregnancy, respectively.

Table 8.1
Demographic characteristics of subjects

Subject	Age (years)	Parity	Ethnic origin	Occupation	DEPCAT status	Gestation (weeks)	Height (cm)	Weight (kg)	Fat mass(kg)	Fat-free mass (kg)	BMI (kg/m^2)
Early Pregnancy											
1[a]	32.0	4	British white	Housewife	6	22.9	157	117.8	58.9	58.8	47.8
2[b]	35.1	0	British white	Web designer	4	22.6	160	105.4	51.1	54.4	41.2
3	30.3	1	British African	Housewife	3	23.1	172	121.6	58.6	61.0	46.7
4	25.7	2	British white	Housewife	5	18.6	160	119.6	57.6	60.9	48.1
Late Pregnancy											
5[a]	32.0	4	British white	Housewife	6	30.7	157	118.2	59.3	58.8	47.9
6[b]	35.1	0	British white	Web designer	4	30.3	160	112.2	50.2	56.1	45.0
7	39.2	0	British white	Nurse	4	34.0	157	118.2	59.3	58.8	47.9
8	31.6	0	British white	Social worker	4	30.0	160	106.2	50.2	56.1	41.5

BMI – Body mass index; DEPCAT – Deprivation category
[ab] Same individuals

There was a trend for the mean for TEE (in kcal/day and kcal/kg fat-free mass/day) to be lower during early as compared to late pregnancy (Table 8.2). This was due to the extremely high TEE value in Subject 7. Excluding this extreme value, the mean for TEE was almost similar between early and late pregnancy. In the two subjects with paired data for early and late pregnancy, TEE was found to be reduced in Subject 1, whereas this was increased in Subject 2. This was comparable to their gestational weight gain (GWG) where Subject 1 lost 1kg of weight but Subject 2 gained 4.4kg. Subject 1 also had a baby with smaller birth weight (BWT) as compared to Subject 2, even though both of them had girls. Mean (± SD) ratios of TEE to basal metabolic rate (BMR) were 1.69±0.13 for early and 2.03±0.75 for late pregnancy. After excluding Subject 7, the ratio was 1.67±0.24 for late pregnancy, which was similar to early pregnancy values.

Table 8.2
Mean (SD) of TEE, BMR, reported energy intake and total physical activity, total GWG and baby birth weight.

Subject	TEE[c] (kcal/day)	TEE[c] (kcal/kg FFM/day)	BMR[d] (kcal/day)	Reported EI (kcal/day)[e]	Reported AEE (kcal/day)[f]	Ratio TEE:BMR	Ratio EI:TEE	Ratio AEE:TEE	Total GWG[g] (kg)	Baby birth weight (g)
Early Pregnancy										
1[a]	3405	57.8	1941	2060	2163	1.75	0.60	0.64	-1.0	3140
2[b]	2724	50.1	1789	1411	4987	1.52	0.52	1.83	4.4	3450
3	3604	59.1	1985	2160	4538	1.82	0.60	1.26	6.2	3700
4	3324	54.6	1972	812	2616	1.69	0.24	0.79	12.7	4040
Mean	3264	55.4	1922	1611	3576	1.69	0.49	1.13	5.6	3582
SD	379	4.0	90	628	1395	0.13	0.17	0.54	5.7	381
Late Pregnancy										
5[a]	3082	52.4	1938	2143	4093	1.59	0.70	1.33	-1.0	3140
6[b]	3517	62.7	1811	1862	4652	1.94	0.53	1.32	4.4	3450
7	5833	99.2	1877	3976	2036	3.11	0.68	0.35	8.1	4110
8	2768	49.3	1878	2215	842	1.47	0.80	0.30	5.4	3670
Mean	3800	65.9	1876	2549	2906	2.03	0.68	0.83	4.2	3592
SD	1390	22.9	52	963	1777	0.75	0.11	0.58	3.8	408
Late Pregnancy (without extreme value)										
Mean	3122	54.8	1876	2073	3196	1.67	0.68	0.98	2.9	3420
SD	376	7.0	64	186	2057	0.24	0.14	0.59	3.4	266

EI - Energy intake; FFM – Fat free mass, NA - Not available; SD – Standard deviation
[ab] Same individuals
[c] TEE - Total energy expenditure measured by doubly-labelled water;
[d] BMR - Basal metabolic rate measured by using body composition analyzer
[e] EI - Reported energy intake from food frequency questionnaire
[f] AEE - Reported activity energy expenditure in kcal/day as estimated from values reported in MET-hours/day X weight (kg)
[g] Total gestational weight gain measured as difference in weight at 1st visit and weight at 36 weeks

There was a trend for a positive correlation between TEE and reported total energy intake (Figure 8.1a), although this was no longer observed when the extreme value was removed (Figure 8.1b). Similarly, an inverse trend of correlation was seen between TEE and reported total activity, but only if the extreme value was included (Figures 8.2a and 8.2b). In terms of reporting accuracy, all of the subjects were found to under-report their energy intake by about 32 – 51% based on the mean of EI:TEE ratios (Table 8.2). The largest discrepancy between TEE and EI was seen in Subject 4 who reported energy intake which was 76% lower than her energy requirement, despite gaining the most GWG and delivering one of the largest babies in the group. On the other hand, 50% of the subjects were found to be over-estimating their activity energy expenditure (AEE) when this was self-reported to be higher than their measured TEE, as demonstrated by the AEE:TEE ratios.

Figure 8.1a

Correlation between total energy expenditure measured by DLW method and reported total energy intake, both in kcal/day (n=8)

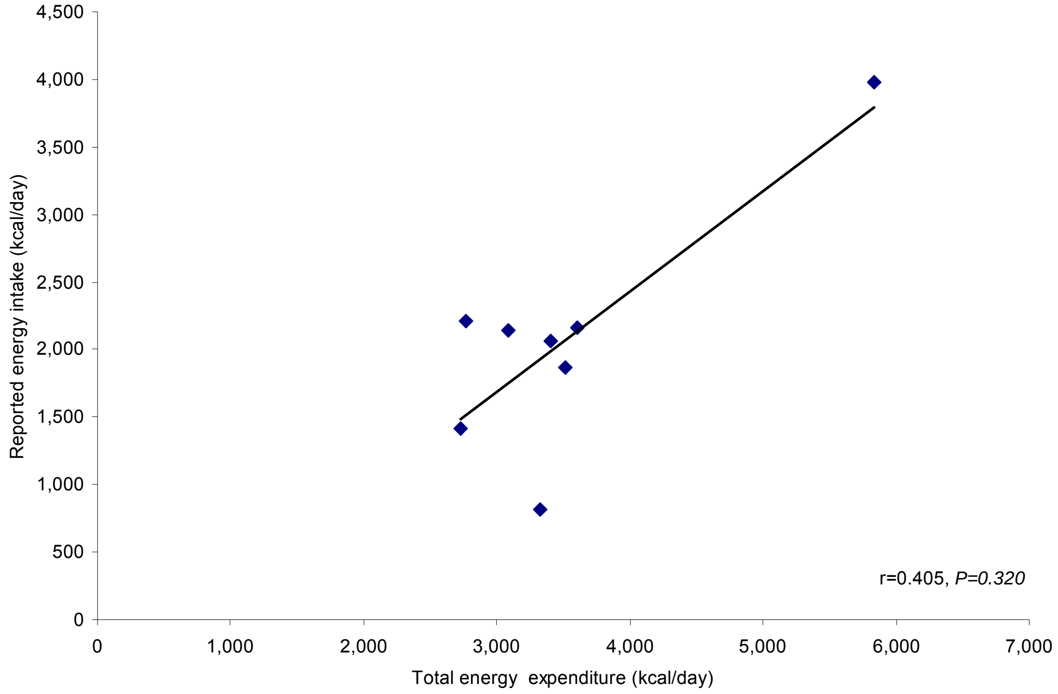


Figure 8.1b

Correlation between total energy expenditure measured by DLW method and reported total energy intake, both in kcal/day, without extreme value (n=7)

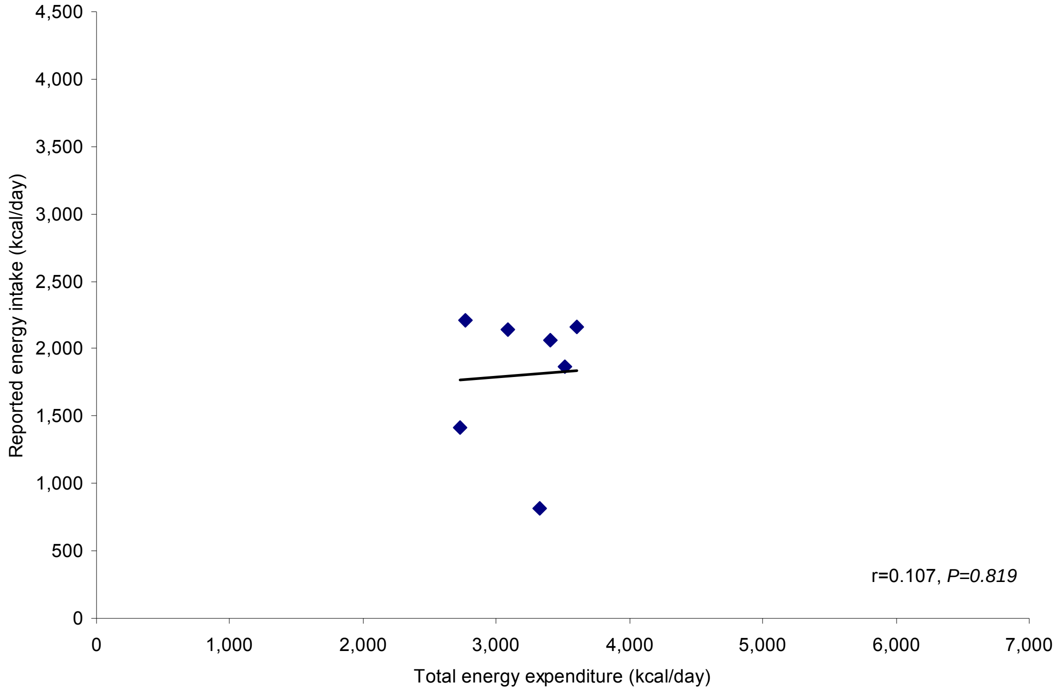


Figure 8.2a

Correlation between total energy expenditure measured by DLW method and reported total activity energy expenditure, both in kcal/day (n=8)

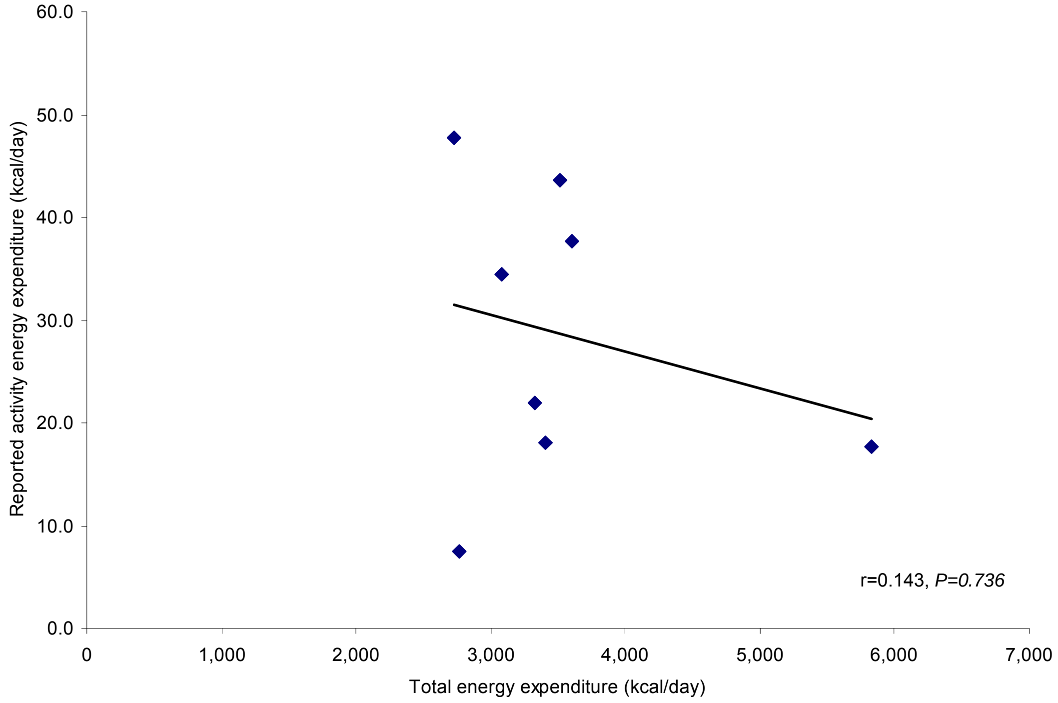
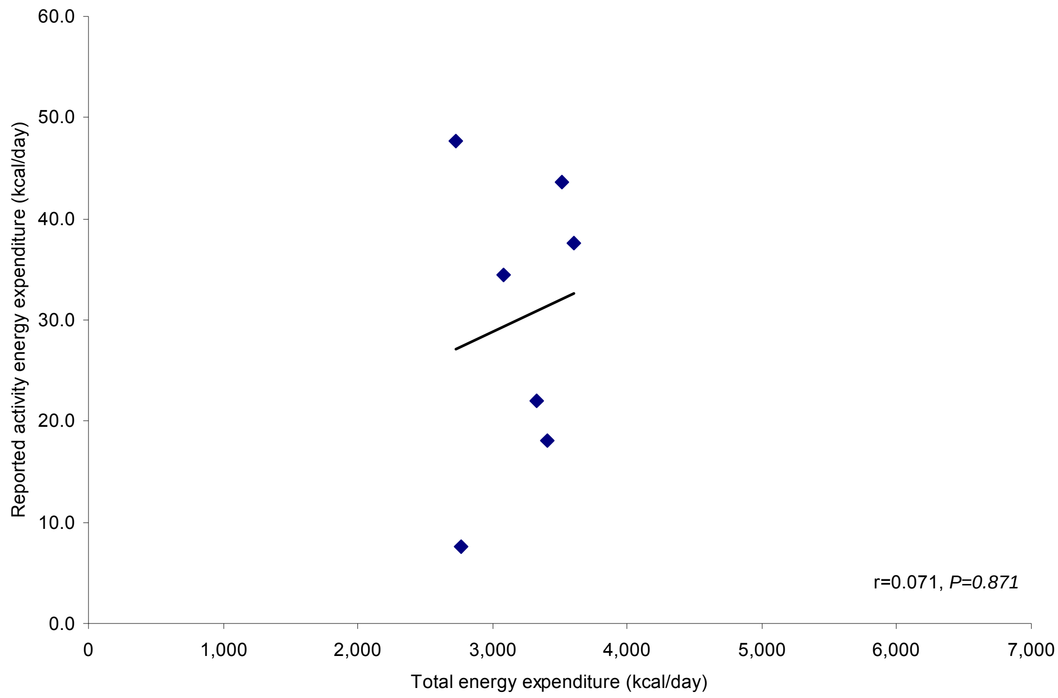


Figure 8.2b

Correlation between total energy expenditure measured by DLW method and reported total activity energy expenditure, both in kcal/day, without extreme value (n=7)



8.5 Discussion

In this chapter, TEE of a small group of severely obese pregnant women was objectively measured by using the DLW, a technique considered the benchmark for this purpose. It was carried out as a pilot study to determine the feasibility of DLW assessment for use in future and possibly larger studies.

The DLW technique provides a unique tool for assessing energy requirement in humans. Based on the First Law of Thermodynamics introduced by Rudolph Clausius in 1850, energy is conserved and cannot be created or destroyed. The energy put into a system is equivalent to the energy used and/or stored by the system. In humans, energy intake is equivalent to energy expenditure (plus any change stored in the body) assuming that weight is stable and not in an active stage of growth. A study in 319 men and women demonstrated that TEE substantially and progressively increased in obesity (Prentice et al, 1996b). In female participants, TEE increased from 2,378 kcal/day in normal weight subjects to 3,226 kcal/day in those with BMI>35kg/m^2. In pregnancy, studies in normal weight women showed that TEE generally increased with advancing gestation by 1%, 6% and 9% over pre-pregnancy values, in the 1st, 2nd, and 3rd trimesters, respectively (Butte and King, 2005). In a longitudinal study in 12 lean women from prior to conception and through pregnancy, Goldberg et al (1993) found that TEE was: pre-pregnancy 2,275kcal/day; at 18 weeks 2,457 kcal/day; at 24 weeks 2,622 kcal/day and at 36 weeks 2,689 kcal/day. Other studies with similar design found that TEE in the first trimester of pregnancy tended to be lower (Forsum et al, 1992) or similar to (Kopp-Hoolihan et al, 1999) pre-pregnancy values but then increased quite dramatically in the second trimester. This different pattern in TEE changes suggests a vast amount of individual variability in the metabolic changes that occur during pregnancy. This was also seen in our subjects with paired data for early and late pregnancy (Subjects 1/5 and 2/6). One subject's TEE was reduced from early to late pregnancy whereas the other's was markedly increased. The subject with decreased TEE lost weight during pregnancy (despite self-reports of higher energy intake and lower AEE) and had a baby with smaller BWT. On the other hand, the subject with raised TEE gained weight and had a heavier baby.

In general, TEE is also increased in obese pregnancy. A longitudinal study which included 12 'high-BMI' (BMI>26.0, 8 overweight and 4 obese) pregnant women showed an increment of TEE throughout pregnancy (Butte et al, 2004). The TEE recorded were: pre-pregnancy 2,074 kcal/day; at 9 weeks 2,145kcal/day; at 22 weeks 2,245 kcal/day, and at 36 weeks 2,595kcal/day. These values were higher than of their normal-BMI subjects (BMI 19.8-26.0, n=34) with TEE: pre-pregnancy 1,760 kcal/day; at 9 weeks 1,771kcal/day; at 22 weeks 1,854 kcal/day, and at 36 weeks 2,164kcal/day. The TEE values of their high-BMI subjects were lower compared to values found in this study. This could be because the BMI of their high-BMI subjects was much lower (28.8±2.6kg/m^2) as compared to the BMI of subjects in this study (45.8±1.5kg/m^2). As in general pregnant women populations, the increased TEE in obese pregnancy includes an increment in BMR as a result of higher tissue mass (Butte et al, 2004).

Development of the DLW method has also made it possible to assess the accuracy of self-reported dietary intake. An extensive review (Trabulsi and Schoeller, 2001) demonstrated that true energy intake was consistently under-reported by certain groups within the population, regardless of the dietary instruments used. This has been supported by other DLW studies which indicated that energy intake was more frequently under-reported in women as compared to men (Seale and Rumpler, 1997), and more in obese than lean women (Prentice et al, 1986). In the current study, reported energy intake only comprised of an average 68% of measured TEE, indicating a substantial degree and prevalence of under-reporting of energy intake among the study participants. This supported a previous finding of this thesis where comparison of reported energy intake at 28 weeks gestation against estimated energy requirement showed that under-reporting occurred in about half (49%) of the obese group, as compared to 15% in lean (refer chapter 5 for details). It was also found that obese had a higher degree of energy underreporting with an average of 72% of estimated energy requirement as opposed to 95% in their lean counterparts.

In an attempt to establish the relative accuracy of prospective (e.g. food diary) and retrospective (e.g. 24-hour recall, diet history and food frequency questionnaire), two studies found that neither was consistently more accurate than the other even when this was assessed in the same individuals (Scagliusi et al, 2008, Trabulsi and Schoeller, 2001), and that none of the instruments showed greater accuracy than the DLW technique (Trabulsi and Schoeller, 2001). In view of these findings, self-reported food intake should be interpreted with caution due to it being subject to reporting bias particularly in certain groups of people who have been associated with reporting inaccuracy, unless independent (and ideally objective) methods of assessing their validity are included in the study design. Observer-recorded food records may be able to improve the accuracy of food intake data in this population. A study on 22 male and 32 female overweight and obese subjects demonstrated that a combination of observer-recorded food records and 24-hour snack recalls method is a valid method for measuring energy intake in their study population (Hise et al, 2002). Mean energy intake was not significantly different from mean TEE and they observed no changes in body weight of their subjects (Hise et al, 2002).

Other than under-reporting their food intake, this study also indicated that this group of severely obese pregnant women also tended to over-estimate their self-reported PA. About half of the women studied had AEE:TEE ratios more than the value of 1. This was consistent with the findings from Chapter 6 of this thesis, where it was found that even though the obese group reported their amounts of total activity to be similar to lean group throughout pregnancy (after adjustment for confounding factors), objective accelerometry assessment indicated that activity counts were actually lower in obese as compared to lean. Longitudinal studies which measured both TEE (by using DLW method) and BMR (by using indirect calorimetry) and thus were able to calculate AEE (as TEE - (BMR + thermic effect of food (10% TEE)) showed similar pre-pregnancy AEE values (39-40% of TEE) in lean (Kopp-Hoolihan et al, 1999) and obese pregnant women (Butte et al, 2004). During pregnancy, AEE was reported to be constant in lean pregnant women, with 36.3% in 1st trimester, 35.9% in 2nd trimester, and 38.7% in 3rd trimester (Kopp-Hoolihan et al, 1999). On the other hand, in obese pregnant women, AEE decreased from early (31%) to late pregnancy (23%) (Butte et al, 2004). Inaccuracy of self-reported PA as compared against objective assessments including DLW and indirect calorimetry, has previously been reported and was associated with body fatness (Irwin, Ainsworth and Conway, 2001, Buchowski et al, 1999) and sedentary lifestyle (Duncan et al, 2001).

This study is subject to several limitations. The relative high cost of the DLW technique limited the number of participants. The poor response from the obese group where only ~50% agreed to participate when approached for the study increased participation bias as only the more motivated subjects agreed to participate. In this study, BMR was not measured using an indirect calorimetry method, as it should have been done ideally (due to unavailability of equipment) but was obtained from a body composition analyzer which used a bioelectrical impedance technique. This equipment uses regression prediction equations based on age, gender, height, weight and other body composition information (Jebb et al, 2000), and therefore may not be as accurate as indirect calorimetry.

It was also found that one of the subjects in this study (Subject 7) had an unusually high TEE, the reason of which was not totally clear. Although this subject was on thyroid hormone replacement therapy for her hypothyroidism, it had been confirmed prior to her inclusion in the study that this should not affect the TEE outcome. It was also agreed that this abnormal value was not due to analytical error as this value was averaged from the readings of 4 samples. This subject, however, had gained weight within healthy recommendation (8.1kg) and gave birth to a baby boy weighing more than 4,000g.

In conclusion, data obtained through DLW method demonstrated that there is great variability in TEE of severely obese pregnant women. TEE was found to increase in one but to reduce in another subject, although at the group level, the mean TEE did not seem to change much from early to late pregnancy. This could be due to metabolic changes taking place during pregnancy, which affect different individuals differently. The measured TEE also showed that that there is indeed a trend for under-reporting of energy intake as well as over-reporting of PA in this study population, which suggests that self-reported technique may not be a suitable method to obtain accurate diet and PA information from severely obese pregnant women, confirming the findings of previous chapters (Chapter 5 and 6) of this thesis. Based on the result of this pilot study, DLW appears to be useful for assessment of TEE and validation of reported dietary intake and PA and should therefore be replicated in a future study with a larger number of participants.

CHAPTER 9

Conclusion

Chapter 9

The prevalence of obesity in pregnancy is on the increase in parallel with the obesity incidence in the general population, including in Scotland (Gray and Leyland, 2009). The associated complications of maternal obesity have been well documented and these affect both the health of mother and baby, in short- as well as long-term (Davies et al, 2010, Heslehurst et al, 2008, Catalano and Ehrenberg, 2006). Obesity may be explained by energy intake in excess of requirement, as well as, inadequate physical activity (PA). In pregnancy, these modifiable factors have been targeted in intervention studies with regard to prevention of excessive gestational weight gain (GWG) and unhealthy birthweight (BWT). However, very little is known about diet and PA in severely obese pregnancy, a population in whom these interventions would be assumed to be of most benefit. There are no studies reporting whether diet and/or PA affect GWG and BWT in this population.

Against this background, this research aimed to investigate dietary and PA behaviours in severely obese pregnant women, compared with information obtained from lean pregnant controls, among women recruited from an ongoing prospective cohort study of severe obesity in pregnancy. In doing so, this research also aimed to evaluate the validity of the self-reported instruments used, as well as the prevalence of underreporting of self-reported energy intake in this study population. The associations between diet and PA and GWG/BWT were also investigated to assess the possible role of these in determining pregnancy and birth outcomes.

The Scottish Collaborative Group Food Frequency Questionnaire (SCG-FFQ) has been previously used in studies involving Scottish pregnant women population However, its validity has never been tested for use in obese pregnancy, and this was done by comparing the intakes of total energy and nutrients as reported in the SCG-FFQ to those recorded in a 4-day food diary in a subgroup of the study population. The results described in Chapter 3 showed that the correlations of total energy and nutrients (except for dietary fibre) in the obese group, were lower than in the lean group, but were comparable to other studies. Cross-classification and weighted kappa values were also found to be lower in obese than lean, in agreement with the results obtained from the correlation methods. This findings suggested reasonable validity of the SCG-FFQ for assessing dietary intake of obese women during pregnancy in the whole study population. The main limitation of the validation study was that both the study (SCG-FFQ) and reference (food diary) methods were self-reported in nature, and thus could be subjected to similar reporting bias and measurement errors, particularly when the incidence of low reporting accuracy was found (in Chapter 5) to be high in the obese women. Ideally, objective biological measures of total energy or of other biomarkers such as nitrogen, sodium, and certain vitamins, should be included as the reference method to validate a subjective dietary assessment tool.

Having validated the dietary questionnaire, the results discussed in Chapter 4 using the SCG-FFQ, showed that reported total energy intakes were not significantly different between obese and lean groups throughout pregnancy, even though obese women did report to significantly reduce their energy intake from early to late pregnancy. Despite reporting similar energy intake, the diet of obese women was generally of poorer quality than the lean group, containing significantly lower amounts of dietary fibre, as well as of nutrients which are essential during pregnancy such as calcium, iron, vitamin D, and folic acid. Furthermore, a higher percentage of obese women than lean did not meet the recommended nutrient intakes set for these nutrients. These findings were contrary to the original hypothesis that obese women would consume higher total calories than lean. Therefore, further questionnaires were administered to understand more about the eating behaviours of the severely obese women. The principal finding was that the reported reduction in caloric intake from early to late pregnancy in obese women was not associated with the reduced reported appetite or general nutrition knowledge, but was influenced by environmental cues of eating such as the smell, sight, and taste of foods. These findings suggest that interventions targeted at improving dietary intake in severely obese women should look at equipping them with nutrition knowledge and take into account other factors that may influence dietary intake such as appetite and eating behaviours.

The fact that obese women in this study reported to be eating similar amounts of energy intake to lean during both early and late pregnancy raised a question about the accuracy of reporting in this group. This was investigated in Chapter 5 via comparison of reported energy intakes against estimated energy requirement calculated using equations published by the Institute of Medicine, IOM (2002) specifically for overweight pregnant women. Indeed, it was revealed that under-reporting was prevalent among a larger number of participants, as well as to a higher degree, in obese as compared to lean, groups. There was also a trend for selective under/over-reporting where intakes of total fats and dietary cholesterol was lower, whereas intakes of dietary fibre, vitamin C, folic acid and iron were higher, in under-reporters compared to adequate or over-reporters, particularly in obese group. These findings were not entirely surprising as the three characteristics of the study population of being female, obese, and pregnant, are traits which individually in population studies are associated with misreporting of dietary intake. As low reporting accuracy may hinder the ability to determine habitual dietary intake, it may be useful in future studies to include an objective assessment such as measurement of biomarkers or serum micronutrient levels alongside the subjective dietary assessment to evaluate the true nutritional status of these severely obese women during pregnancy.

Apart from diet, PA is another modifiable factor that contributes to energy balance via its effect on energy expenditure. Chapter 6 discussed the assessment of PA using the self-administered Pregnancy Physical Activity Questionnaire (PPAQ), and also quantitatively in a subgroup using accelerometry. The findings discussed in Chapter 6 showed that reported total PA was not significantly different between obese and lean groups, both during early and late pregnancy, after adjustment for confounders. Obese women also reported to be doing more light-weight and household/childcaring activity (results were significant only before adjustment for confounding factors) and less of vigorous-intensity and sports/exercise activities than lean, during both early and late pregnancy. These findings were also contrary to the original hypothesis that obese women would do less PA, but were not fully supported by the accelerometry data which demonstrated that obese had significantly lower total activity counts/min during both early and late pregnancy. Accelerometry data also showed that obese had significantly higher PA energy expenditure (adjusted for fat-free mass) for light-weight activity, than lean during early and late pregnancy. Comparison between these two PA assessment methods revealed that relative validity and reliability of the PPAQ was lower in obese, compared to lean, which may explain the discrepancies in the findings. Chapter 6 also showed that a smaller number of obese women were able to meet healthy PA recommendations for pregnant women than lean, which suggests that severely obese women were indeed less active, at least with regard to recreational activities, than lean, during pregnancy. The use of questionnaires does have an advantage of providing detailed information on the types and duration of specific activities (Rousham, Clarke and Gross, 2006). However, future studies should consider refining the PPAQ particularly in estimation of sedentary activities in order for it to be more suitable for use in severely obese pregnant women. Likewise, the findings of this chapter suggest that objective measurements such as motion sensors (accelerometers or pedometers) should be used together with self-reported instrument assessments in order to provide more accurate estimates of PA and remove many of the issues of recall, perception, or response bias in this population.

In Chapter 7, associations of reported food intake and PA with GWG and BWT were investigated to determine the potential role of diet and PA in affecting pregnancy and birth outcomes in severely obese pregnancy. Findings discussed in this chapter indicate that obese women only gained half as much weight as lean controls. GWG in obese was not associated with the self-reported reduced energy intake, or the reported PA, but was influenced by increasing level of general nutrition knowledge and higher scores of restraint eating behaviour. None of these factors, including GWG, was associated with BWT in this group. Adjustment of total energy intake for reporting accuracy in a subgroup did not alter the results, suggesting that the higher rates of misreporting in the obese group were not a major confounding factor. These findings were different from observations in lean, and these suggest that some other factors (beyond what was covered by this study) may play a role in determining pregnancy and birth outcomes in severely obese pregnancy. All obese women in the group did receive dietary advice about healthy eating during pregnancy from a specialised dietitian and were weighed at each clinic visit as part of the routine antenatal care. This may have made them more conscious about their eating patterns and GWG. However, other studies in less severely obese women, have not found that similar interventions have a major impact on GWG (Asbee et al, 2009, Jeffries et al, 2009).

As so little is known about the energy requirement of obese pregnant women, the IOM were not able to provide specific GWG recommendations by obesity class or to support weight gains of below 5kg in this population (Rasmussen et al, 2010). Chapter 8 discusses the use of doubly-labelled water (DLW) to assess total energy expenditure (TEE, which defines energy requirement) in a pilot study on a small group of the severely obese pregnant women. The different pattern of TEE changes, which suggests great individual variability in terms of metabolic response to pregnancy, as reported by others in general pregnant women (Butte et al, 2004, Kopp-Hoolihan et al, 1999, Goldberg et al, 1993, Forsum et al, 1992), was also evident in this study population. Subjects with paired data available in early and late pregnancy, showed that TEE was increased in one (resulting in increased GWG and heavier baby BWT), but was reduced in another (resulting in weight loss in pregnancy and smaller baby BWT). However, at this study population level, the mean measured TEE did not significantly change between early and late pregnancy and larger numbers would be needed to investigate this further. The DLW technique also allowed for the accuracy of self-reported energy intake and PA to be evaluated. This seems to confirm the prevalence of under-reporting of energy intake, an additionally, of over-reporting of PA, in this group, which again, supports the use of more objective measures rather than just self-reported methods to obtain accurate information from severely obese pregnant women.

Among the strengths of this exploratory project was it being the first study to assess diet and PA in severely obese pregnancy, with the inclusion of lean pregnant women as control group for comparison purposes. The food frequency and PA questionnaires used in this thesis have been extensively used in pregnant women populations previously. In the current project, these questionnaires were validated in subgroups of participants; the SCG-FFQ was validated against 4-day food diary, whereas the PPAQ was compared against quantitave measurement from accelerometry. In addition, reporting accuracy was assessed in most participants and this enabled for associations between diet/PA and GWG/BWT to be adjusted for possible effect of measurement errors. The TEE measured by DLW technique has also provided insightful information However, there were several limitations. The self-reported method used was subject to cognitive ability, as well as memory and social desirability bias. There were also slightly different demographic characteristics between obese and lean groups where obese group had lower rate of nulliparity and lower deprovation category (DEPCAT) status than lean, although these were controlled for in most of the assessments carried out in this thesis.

The relatively small sample size has also caused some studies in this thesis to have low statistical power particularly for the assessments of total calories which were only between 16-33% (as presented in Table 2.1). This was probably due to the large variation between subjects and may have been influenced by reporting accuracy. Is was estimated that in order to achieve 80% power based on the results obtained, sample size should at least be n=471 per group to detect 5% significance level between obese and lean groups. The accelerometry study was also slightly underpowered at ~70%. An additional 5 participants per group should improve the power to reach the conventional 80% level. However, poor participation rate from the obese group caused the recruitment for this study to be very slow and this has hampered the effort to get more participants within the stipulated timeframe. The DLW study provided valuable information regarding TEE of severely obese pregnant women. This allowed for estimation of sample sample size if the study were to be replicated in future, in both obese and lean groups. Using normal-weight pregnant women data from the literature (Butte et al, 2004), it is estimated that n=7 for each group (assuming participants are to be followed up longitudinally) in order to reach 80% power and detect 5% significance between groups.

Assessment of diet and PA in pregnant women is complicated. Pregnancy is a complex period with dynamic metabolic, physiological and psychological demands which may influence maternal food intake and PA behaviours in ways that are unique to every woman – an enigma which still baffles many researchers. Pregnancy associated with severe obesity is an even more poorly understood area. Findings from this research suggest that self-reported questionnaires may not be the best method to elicit true information regarding dietary or PA behaviours from severely obese pregnant women. If for reason of practicality, cost, improved acceptance by study participants, or concern about inducing socially-desirable reporting biasness (e.g. with use of interviewer-administered method) the self-administered method is chosen, then care should be taken in handling and interpreting the results. The application of statistical adjustments such as the residual or energy density methods to reduce the effect of energy underreporting on intakes of nutrients can address bias resulting from self-reports (as discussed in Chapter 5). However, whenever possible, objective assessments should ideally be used to substantiate subjective methods in order to improve accuracy and interpretation of results in this study population.

The findings of this research provided some useful clinical applications. It was demonstrated that severely obese women reported to be consuming similar total energy to lean women, but their diet was of poorer quality during both early and late pregnancy. This suggests that health practitioners should not focus solely on calorie control when discussing food intake with obese pregnant mothers but also to educate them about nutrient content of foods. The equal importance between quantity and quality of diet must be emphasized. Any intervention to improve dietary quality in obese women should consider eating behaviours including restrained, emotional, and externally cued eating, which impact on food choices. In terms of PA, although obese women also reported doing similar amounts of total PA to lean, this was comprised of more of light-weight and household/childcaring activities and less of vigorous-intensity and sports/exercise activities. In addition, a larger proportion of obese women were not as physically active as recommended during pregnancy compared to their lean counterparts. Therefore, interventions to modify PA levels in obese may need to include more light-to-moderate intensity activities and encouraged through modification of behaviours, as opposed to through prescription of formal exercise routines.

In terms of future perspectives, deally, other than using both subjective and quantitative instruments to assess food intake and PA, studies replicating the project presented in this thesis in the future should be carried out longitudinally to reduce inter-subject variation, increase statistical power, and to improve accuracy of results. In addition, more frequent assessments such as 3-4 times during pregnancy together with postnatal follow-ups and collection of pre-pregnancy history would provide more insight and may increase our understanding regarding diet and PA behaviours in severely obese pregnancy. In this thesis, the lack of association between reported total energy and total PA with GWG or BWT in the obese group warrants further investigation to understand how severely obese women respond to pregnancy metabolically such as how they store and use energy and nutrients during pregnancy in order to understand the potential impact of energy intake and PA on GWG and BWT in this population.

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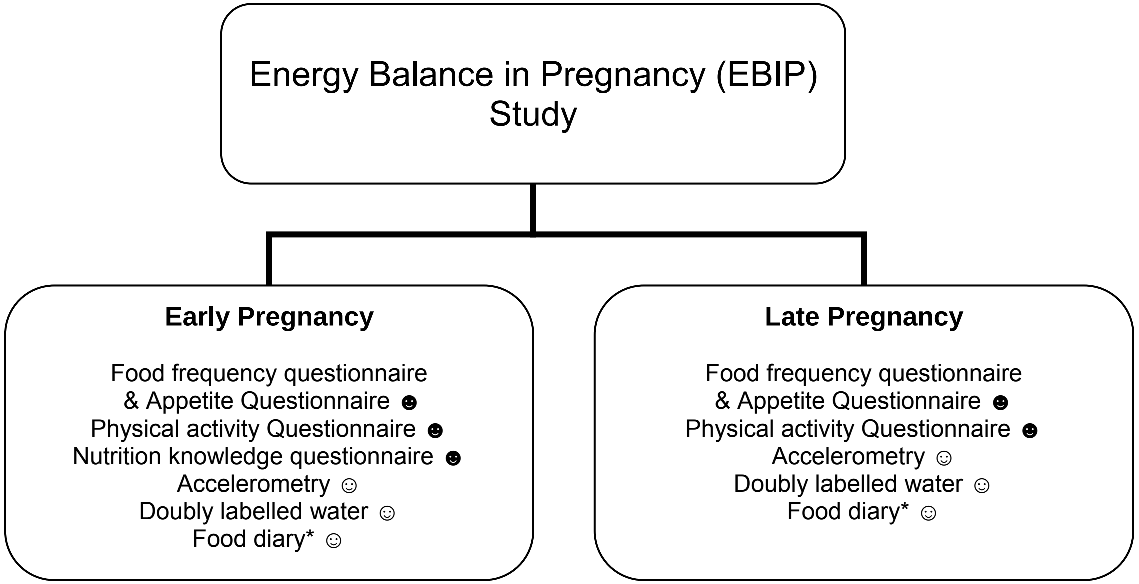
Appendices

Appendix A
The study protocol for the EBIP study



☻ Given out routinely
☺ Invited by personal approach
* Completed once either in early or late pregnancy

Appendix B

Comparison of demographic characteristics between subjects who were included in the HIP and EBIP studies

		Obese Group							Lean Group						
		HIP Study participants (n=218)		EBIP Study participants (n=175)		EBIP Study non-participants (n=43)			HIP Study participants (n=88)		EBIP Study participants (n=87)		EBIP Study non-participants (n=1)		
		Mean	(SD or %)	Mean	(SD or %)	Mean	(SD or %)	*P Value**	Mean	(SD or %)	Mean	(SD or %)	Mean	(SD or %)	*P Value**
Age (years)		31.3	(5.4)	31.4	(5.4)	31.0	(5.4)	*P=0.551*‡	33.3	(4.6)	33.4	(4.5)	27.1		*P=NC*
BMI (kg/m^2)		44.3	(4.3)	44.1	(4.5)	44.6	(4.2)	*P=0.611*‡	22.7	(1.7)	22.6	(2.0)	23.1		*P=NC*
Parity	Nulliparous	124	(50.7%)	83	(48.3%)	27	(62.8%)	*P=0.071*†	56	(63.6%)	55	(63.2%)	1	(100%)	*P=NC*
	Multiparous	114	(49.3%)	89	(51.7%)	16	(32.7%)		32	(36.4%)	32	(36.8%)			
Ethnicity	Caucasian	209	(96.0%)	167	(95.4%)	42	(97.7%)	*P=0.507*†	88	(100%)	87	(100%)	1	(100%)	*P=NC*
	Non-Caucasian	9	(4.0%)	8	(4.6%)	1	(2.3%)								
DEPCAT	Low	38	(17.3%)	27	(15.4%)	14	(32.6%)	*P=0.004*†	1	(1.1%)	1	(1.1%)			*P=NC*
	Middle	160	(73.3%)	133	(76.6%)	22	(51.2%)		61	(69.3%)	60	(69.0%)	1	(100%)	
	High	20	(9.4%)	14	(8.0%)	7	(16.2%)		26	(29.6%)	26	(29.9%)			

HIP – Hormones and Inflammation; EBIP – Energy Balance in Pregnancy; SD – Standard deviation; BMI – Basal metabolic index (at booking); NC – Not calculated; DEPCAT – Deprivation Category status

* Comparison between EBIP study respondents and non-responders; ‡ Tested using independent t-test; † Tested using chi square test

Appendix C
Comparison of demographic characteristics between obese and lean subjects who were included in the EBIP study

		Obese Group (n=175)		Lean Group (n=87)		
		Mean	(SD or %)	Mean	(SD or %)	*P Value*
Age (years)		31.4	(5.4)	33.4	(4.5)	*P=0.004*‡
BMI at booking (kg/m^2)		44.1	(4.5)	22.6	(2.0)	*P<0.001*‡
Parity	Nulliparous	83	(48.3%)	55	(63.2%)	*P=0.016*†
	Multiparous	89	(51.7%)	32	(36.8%)	
Ethnicity	Caucasian	167	(95.4%)	87	(100%)	*P=0.043*†
	Non-Caucasian	8	(4.6%)			
DEPCAT	Low	27	(15.4%)	1	(1.1%)	*P<0.001*†
	Middle	133	(76.6%)	60	(69.0%)	
	High	14	(8.0%)	26	(29.9%)	

HIP – Hormones and Inflammation; EBIP – Energy Balance in Pregnancy; SD – Standard deviation; BMI – Basal metabolic index; DEPCAT – Deprivation Category status
‡ Tested using independent t-test; † Tested using chi square test

Appendix D

Comparison of demographic characteristics between subjects who did and did not participate in the Scottish Collaborative Group Food Frequency Questionnaire validation study

		Obese Group					Lean Group				
		Participants (n=31)		Non-participants (n=187)			Participants (n=37)		Non-participants (n=56)		
		Mean	(SD or %)	Mean	(SD or %)	*P Value*	Mean	(SD or %)	Mean	(SD or %)	*P Value*
Age (years)		33.8	(5.8)	31.0	(5.3)	*P=0.015*[‡]	33.3	(5.1)	33.3	(4.4)	*P=0.991*[‡]
BMI at booking (kg/m^2)		43.4	(2.6)	44.3	(4.5)	*P=0.125*[‡]	22.8	(1.8)	22.4	(1.4)	*P=0.184*[‡]
Parity	Nulliparous	18	(58.1%)	92	(49.2%)	*P=0.360*[†]	19	(59.4%)	37	(66.1%)	*P=0.530*[†]
	Multiparous	13	(41.9%)	95	(50.8%)		13	(40.6%)	19	(33.9%)	
Ethnicity	Caucasian	31	(100%)	178	(95.2%)	*P=0.212*[†]	32	(100%)	56	(100%)	*P=NC*
	Non-Caucasian			9	(4.8%)						
DEPCAT status	Low	5	(16.1%)	36	(19.3%)	*P=0.351*[†]	1	(3.1%)			*P=0.170*[†]
	Middle	25	(80.6%)	131	(70.1%)		19	(59.4%)	42	(75.0%)	
	High	1	(3.2%)	20	(10.6%)		12	(37.5%)	14	(25.0%)	

SD – Standard deviation; Basal metabolic index; NC – Not calculated; DEPCAT – Deprivation Category

[‡] Tested using independent t-test; [†] Tested using chi square test

Appendix E
Comparison of demographic characteristics between subjects who did and did not participate in assessment of dietary intake by using the Scottish Collaborative Group Food Frequency Questionnaire

		Obese Group					Lean Group				
		Participants (n=163)		Non-participants (n=54)			Participants (n=85)		Non-participants (n=3)		
		Mean	(SD or %)	Mean	(SD or %)	*P Value*	Mean	(SD or %)	Mean	(SD or %)	*P Value*
Age (years)		31.5	(5.4)	30.8	(5.5)	*P=0.370*‡	33.6	(4.3)	26.3	(4.5)	*P=0.240*‡#
BMI at booking (kg/m^2)		43.9	(4.2)	44.8	(4.3)	*P=0.153*‡	22.5	(1.6)	23.8	(2.0)	*P=0.218*‡
Parity	Nulliparous	77	(47.2%)	32	(59.3%)	*P=0.189*†	53	(62.4%)	3	(100%)	*P=0.183*†
	Multiparous	86	(52.8%)	22	(40.7%)		32	(37.6%)			
Ethnicity	Caucasian	156	(95.7%)	52	(96.3%)	*P=0.961*†	85	(100%)	3	(100%)	*P=NC*
	Non-Caucasian	7	(4.3%)	2	(3.7%)						
DEPCAT status	Low	24	(14.7%)	17	(31.5%)	*P=0.021*†	1	(1.2%)			*P=0.503*†
	Middle	126	(77.3%)	29	(53.7%)		58	(68.2%)	3	(100%)	
	High	13	(8.0%)	8	(14.8%)		26	(30.6%)			

SD – Standard deviation; Basal metabolic index; NC – Not calculated; DEPCAT – Deprivation Category
‡ Tested using independent t-test; † Tested using chi square test; # Equal variances not assumed

Appendix F

Comparison of demographic characteristics between subjects who did and did not participate in assessment of general nutrition knowledge by using the General Nutrition Knowledge Questionnaire

		Obese Group					Lean Group				
		Participants (n=69)		Non-participants (n=149)			Participants (n=57)		Non-participants (n=31)		
		Mean	(SD or %)	Mean	(SD or %)	*P Value*	Mean	(SD or %)	Mean	(SD or %)	*P Value*
Age (years)		32.2	(5.4)	31.0	(5.4)	*P=0.109*‡	33.7	(3.9)	32.6	(5.6)	*P=0.273*‡
BMI at booking (kg/m^2)		43.8	(4.1)	44.4	(4.3)	*P=0.307*‡	22.4	(1.6)	22.9	(1.5)	*P=0.193*‡
Parity	Nulliparous	33	(47.8%)	77	(51.7%)	*P=0.597*†	38	(66.7%)	18	(58.1%)	*P=0.423*†
	Multiparous	36	(52.2%)	72	(48.3%)		19	(33.3%)	13	(41.9%)	
Ethnicity	Caucasian	67	(97.1%)	142	(95.3%)	*P=0.535*†	57	(100%)	31	(100%)	*P=NC*
	Non-Caucasian	2	(2.9%)	7	(4.7%)						
DEPCAT status	Low	10	(14.5%)	31	(20.8%)	*P=0.540*†			1	(3.3%)	*P=0.395*†
	Middle	52	(75.4%)	104	(69.8%)		40	(70.2%)	21	(67.7%)	
	High	7	(10.1%)	14	(9.4%)		17	(29.8%)	9	(29.0%)	

SD – Standard deviation; Basal metabolic index; NC – Not calculated; DEPCAT – Deprivation Category

‡ Tested using independent t-test; † Tested using chi square test

Appendix G
Comparison of demographic characteristics between subjects who did and did not participate in assessment of appetite by using the Council on Nutrition Appetite Questionnaire

		Obese Group					Lean Group				
		Participants (n=71)		Non-participants (n=147)			Participants (n=57)		Non-participants (n=31)		
		Mean	(SD or %)	Mean	(SD or %)	*P Value*	Mean	(SD or %)	Mean	(SD or %)	*P Value*
Age (years)		30.8	(5.3)	31.6	(5.5)	*P=0.344*‡	33.8	(4.0)	32.5	(4.5)	*P=0.266*‡
BMI at booking (kg/m^2)		44.8	(4.5)	43.9	(4.2)	*P=0.174*‡	22.7	(1.4)	22.4	(1.9)	*P=0.503*‡
Parity	Nulliparous	34	(47.9%)	76	(51.7%)	*P=0.598*†	33	(57.9%)	23	(74.2%)	*P=0.129*†
	Multiparous	37	(52.1%)	71	(48.3%)		24	(42.1%)	8	(25.8%)	
Ethnicity	Caucasian	68	(95.8)	141	(95.9%)	*P=0.960*†	57	(100%)	31	(100%)	*P=NC*
	Non-Caucasian	3	(4.2%)	6	(4.1%)						
DEPCAT status	Low	8	(11.3%)	33	(22.4%)	*P=0.108*†			1	(3.2%)	*P=0.353*†
	Middle	57	(80.3%)	99	(67.3%)		39	(68.4%)	22	(71.0%)	
	High	6	(8.4%)	15	(10.3%)		18	(31.6%)	8	(25.8%)	

SD – Standard deviation; Basal metabolic index; NC – Not calculated; DEPCAT – Deprivation Category
‡ Tested using independent t-test; † Tested using chi square test

Appendix H

Comparison of demographic characteristics between subjects who did and did not participate in assessment of dietary behaviours by using the Dutch Eating Behaviour Questionnaire

		Obese Group					Lean Group				
		Participants (n=48)		Non-participants (n=170)			Participants (n=38)		Non-participants (n=50)		
		Mean	(SD or %)	Mean	(SD or %)	*P Value*	Mean	(SD or %)	Mean	(SD or %)	*P Value*
Age (years)		30.6	(5.0)	31.6	(5.6)	*P=0.239*‡	34.2	(3.6)	32.6	(5.2)	*P=0.098*‡
BMI at booking (kg/m^2)		44.8	(4.6)	44.0	(4.2)	*P=0.290*‡	22.6	(1.4)	22.5	(1.7)	*P=0.752*‡
Parity	Nulliparous	22	(45.8%)	88	(51.8%)	*P=0.422*†	24	(63.2%)	32	(64.0%)	*P=0.935*†
	Multiparous	26	(54.2%)	82	(48.2%)		14	(36.8%)	18	(36.0%)	
Ethnicity	Caucasian	45	(93.8%)	164	(96.5%)	*P=0.670*†	38	(100%)	50	(100%)	*P=NC*
	Non-Caucasian	3	(6.2%)	6	(3.5%)						
DEPCAT status	Low	5	(10.6%)	36	(21.2%)	*P=0.545*†			1	(2.0%)	*P=0.671*†
	Middle	38	(78.2%)	118	(69.4%)		27	(71.1%)	34	(68.0%)	
	High	5	(10.6%)	16	(9.4%)		11	(28.9%)	15	(30.0%)	

SD – Standard deviation; Basal metabolic index; NC – Not calculated; DEPCAT – Deprivation Category

‡ Tested using independent t-test; † Tested using chi square test

Appendix I

Comparison of demographic characteristics between subjects who did and did not participate in assessment of reporting accuracy of total energy intake

		Obese Group					Lean Group				
		Participants (n=98)		Non-participants (n=120)			Participants (n=68)		Non-participants (n=20)		
		Mean	(SD or %)	Mean	(SD or %)	*P Value*	Mean	(SD or %)	Mean	(SD or %)	*P Value*
Age (years)		31.9	(5.1)	30.9	(5.7)	*P=0.187*[‡]	33.7	(4.0)	32.1	(6.3)	*P=0.320*[‡]
BMI at booking (kg/m^2)		44.1	(4.2)	44.3	(4.4)	*P=0.696*[‡]	22.5	(1.6)	22.9	(1.5)	*P=0.358*[‡]
Parity	Nulliparous	47	(48.0%)	63	(52.5%)	*P=0.505*[†]	45	(66.2%)	11	(55.0%)	*P=0.361*[†]
	Multiparous	51	(52.0%)	57	(47.5%)		23	(33.8%)	9	(45.08%)	
Ethnicity	Caucasian	96	(98.0%)	113	(94.2%)	*P=0.161*[†]	68	(100%)	20	(100%)	*P=NC*
	Non-Caucasian	2	(2.0%)	7	(5.8%)						
DEPCAT status	Low	15	(15.3%)	26	(21.6%)	*P=0.488*[†]	1	(1.5%)			*P=0.742*[†]
	Middle	73	(74.5%)	83	(69.2%)		46	(67.6%)	15	(75.0%)	
	High	10	(10.2%)	11	(9.2%)		21	(30.9%)	5	(25.0%)	

SD – Standard deviation; Basal metabolic index; NC – Not calculated; DEPCAT – Deprivation Category

[‡] Tested using independent t-test; [†] Tested using chi square test

Appendix J

Comparison of demographic characteristics between subjects who did and did not participate in assessment of activity energy expenditure by using the Pregnancy Physical Activity Questionnaire

		Obese Group					Lean Group				
		Participants (n=155)		Non-participants (n=63)			Participants (n=84)		Non-participants (n=4)		
		Mean	(SD or %)	Mean	(SD or %)	*P Value*	Mean	(SD or %)	Mean	(SD or %)	*P Value*
Age (years)		31.4	(5.4)	31.1	(5.3)	*P=0.686*‡	33.7	(4.3)	24.7	(4.5)	*P=0.204*‡#
BMI at booking (kg/m^2)		44.0	(4.2)	44.8	(4.4)	*P=0.168*‡	22.6	(1.6)	23.2	(2.0)	*P=0.451*‡
Parity	Nulliparous	73	(47.1%)	37	(58.7%)	*P=0.119*†	52	(61.9%)	4	(100%)	*P=0.122*†
	Multiparous	82	(52.9%)	26	(41.3%)		32	(38.1%)			
Ethnicity	Caucasian	149	(96.1%)	60	(95.2%)	*P=0.764*†	84	(100%)	4	(100%)	*P=NC*
	Non-Caucasian	6	(3.9%)	3	(4.8%)						
DEPCAT status	Low	23	(14.83%)	18	(28.6%)	*P=0.011*†	1	(1.2%)	3	(75.0%)	*P=0.953*†
	Middle	120	(77.4%)	36	(57.1%)		58	(69.0%)	1	(25.0%)	
	High	12	(7.7%)	9	(14.3%)		25	(29.8%)			

SD – Standard deviation; Basal metabolic index; NC – Not calculated; DEPCAT – Deprivation Category

‡ Tested using independent t-test; † Tested using chi square test; # Equal variances not assumed

Appendix K

Comparison of demographic characteristics between subjects who did and did not participate in assessment of activity energy expenditure by using accelerometry

		Obese Group					Lean Group				
		Participants (n=22)		Non-participants (n=196)			Participants (n=23)		Non-participants (n=65)		
		Mean	(SD or %)	Mean	(SD or %)	*P Value*	Mean	(SD or %)	Mean	(SD or %)	*P Value*
Age (years)		33.3	(5.5)	31.1	(5.4)	*P=0.080*‡	33.3	(4.6)	33.4	(4.5)	*P=0.980*‡
BMI at booking (kg/m^2)		43.6	(3.2)	44.3	(4.4)	*P=0.452*‡	22.7	(1.7)	22.6	(2.0)	*P=0.886*‡
Parity	Nulliparous	9	(40.9%)	101	(51.5%)	*P=0.345*†	56	(63.6%)	55	(63.2%)	*P=0.409*†
	Multiparous	13	(59.1%)	95	(48.5%)		32	(36.4%)	32	(36.8%)	
Ethnicity	Caucasian	20	(90.9%)	189	(96.4%)	*P=0.217*†	87	(100%)	87	(100%)	*P=NC*
	Non-Caucasian	2	9.1%)	7	(3.6%)						
DEPCAT status	Low	3	(13.6%)	38	(19.4%)	*P=0.505*†	1	(1.1%)	1	(1.1%)	*P=0.440*†
	Middle	18	(81.8%)	138	(70.4%)		61	(69.3%)	60	(69.0%)	
	High	1	(4.5%)	20	(10.2%)		26	(29.6%)	26	(29.9%)	

SD – Standard deviation; Basal metabolic index; NC – Not calculated; DEPCAT – Deprivation Category

‡ Tested using independent t-test; † Tested using chi square test

Appendix L

Comparison of demographic characteristics between subjects who did and did not participate in assessment of association between reported dietary intake/physical activity and gestational weight gain/birthweight

		Obese Group					Lean Group				
		Participants (n=172)		Non-participants (n=46)			Participants (n=83)		Non-participants (n=5)		
		Mean	(SD or %)	Mean	(SD or %)	*P Value*	Mean	(SD or %)	Mean	(SD or %)	*P Value*
Age (years)		31.5	(5.4)	30.8	(5.6)	*P=0.456*[‡]	33.7	(3.9)	26.9	(9.7)	*P=0.189*[‡#]
BMI at booking (kg/m^2)		44.2	(4.3)	44.4	(4.2)	*P=0.726*[‡]	22.5	(1.6)	23.4	(1.3)	*P=0.224*[‡]
Parity	Nulliparous	81	(47.1%)	29	(63.0%)	*P=0.079*[†]	52	(62.7%)	4	(80.0%)	*P=0.434*[†]
	Multiparous	91	(52.9%)	17	(37.0 %)		31	(37.3%)	1	(20.0%)	
Ethnicity	Caucasian	164	(95.3%)	45	(97.8%)	*P=0.453*[†]	83	(100%)	5	(100%)	*P=NC*
	Non-Caucasian	8	(4.7%)	1	(2.2%)						
DEPCAT status	Low	26	(15.1%)	15	(32.6%)	*P=0.006*[†]	1	(1.2%)			*P=0.856*[†]
	Middle	132	(76.7%)	24	(52.2%)		57	(68.7%)	4	(80.0%)	
	High	14	(8.1%)	7	(15.2%)		25	(30.1%)	1	(20.0%)	

SD – Standard deviation; Basal metabolic index; NC – Not calculated; DEPCAT – Deprivation Category

[‡] Tested using independent t-test; [†] Tested using chi square test; [#] Equal variances not assumed

Subject Code | | | | | |

Scottish Collaborative Group Food Frequency Questionnaire version 6.5

Diet Questionnaire

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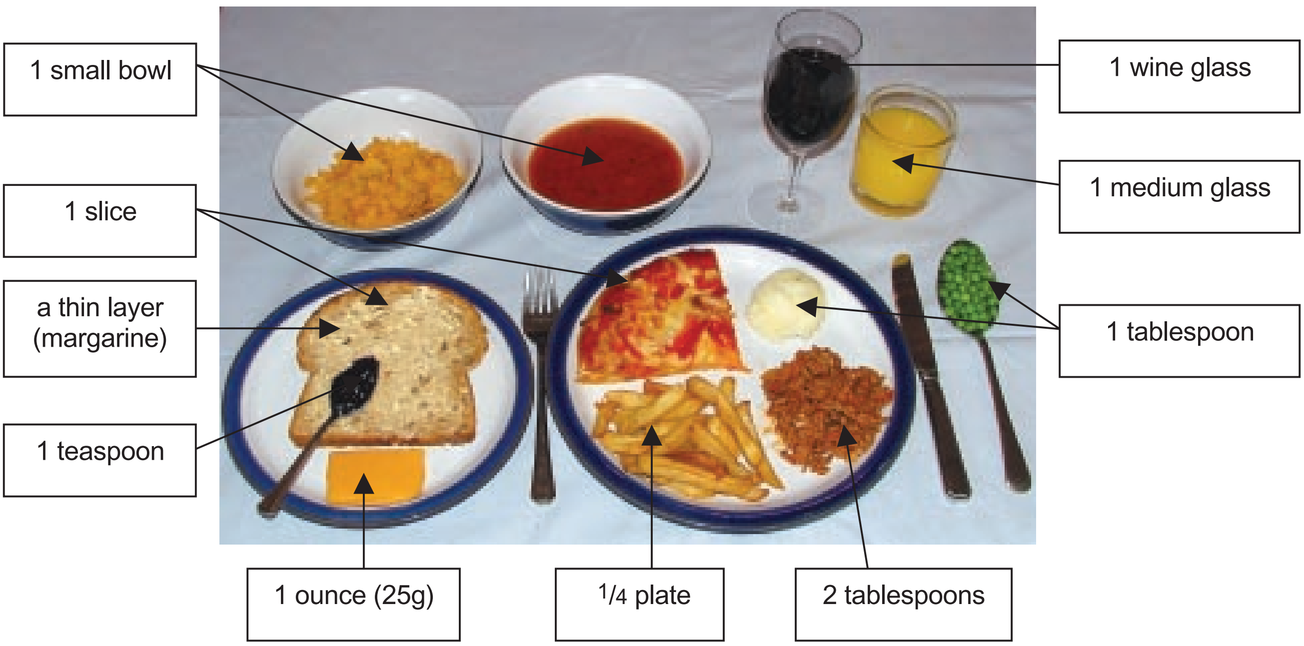
Thank-you for agreeing to complete this questionnaire.
It should take 20-30 minutes to complete.

Please take a few minutes to read the instructions carefully.

SAMPLE

We would like you to describe your usual diet over the last 2-3 months. This should include all your main meals, snacks and drinks which you had at home or away from home e.g. at work, at restaurants or cafes and with friends and family.

The questionnaire lists 170 foods and drinks, and for each one a measure is given to help you estimate how much you usually have. The photograph below shows examples of some of these measures:



Please use **black or blue pen** to complete the questionnaire: do not use pencil.

How to complete the questionnaire

For **every line** in the questionnaire, we would like you to answer two things.

- **how much** of the food you had in a day you ate the food, and
- **how many** days a week you had the food.

To estimate **how much** of the food you had, you should circle a number under 'Measures per day'. Each food is described in common measures such as slices, glasses or tablespoons as illustrated in the photograph. *Please note that the measures are designed to be quite small, so your usual portion may easily be 2 or more measures.*

To estimate **how many** days a week you had the food, you should circle a letter or number under 'Number of days per week'.

- If you had the food less than once a month, you should circle **R** (for **R**arely or never). *For these foods you do not need to fill in the number of measures per day.*
- If you had the food more than once a month but less than once a week, you should circle **M** (for **M**onth).
- If you had the food on average 1-6 days a week, you should circle 1-6 as appropriate.
- If you had the food every day, you should circle 7.

SAMPLE

The example below shows the answers for someone who had 4 slices of bread every day, 1 apple 5 days a week, $^{1}/_{2}$ a plate of chips (i.e. two $^{1}/_{4}$ plates) once or twice a month but rarely or never had tomato juice:

		Measure	Measures per day					Number of days per week								
a)	Bread (including toast & sandwiches)	1 medium slice	1	2	3	4	5+	R	M	1	2	3	4	5	6	7
b)	Apples	1 medium apple	1	2	3	4	5+	R	M	1	2	3	4	5	6	7
c)	Chips from a chip shop or restaurant	$^{1}/_{4}$ plate	1	2	3	4	5+	R	M	1	2	3	4	5	6	7
d)	Tomato juice	$^{1}/_{2}$ medium glass	1	2	3	4	5+	R	M	1	2	3	4	5	6	7

If you want to change an answer, please put a **cross** through the wrong answer and circle the new answer (see example above).

If there are any foods or drinks that you eat regularly which do not appear on the questionnaire, please list them in section 20 ('other foods and drinks').

It is very important that you give an answer for every line.

If you rarely or never have a food, please make sure that you circle R.

1. Breads

		Measure	Measures per day	Number of days per week
a)	Bread (including toast & sandwiches)	1 medium slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Bread roll or bun	1 roll or bun	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Croissants, butteries or garlic bread	1 roll or 2 pieces	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Other breads (pitta, naan, soft tortillas)	1 pitta or 1/2 naan	1 2 3 4 5+	R M 1 2 3 4 5 6 7

e) Which type(s) of bread do you usually eat? **Please tick one or more boxes.** White ☐ Brown / granary ☐ Wholemeal ☐

2. Breakfast Cereals

SAMPLE

		Measure	Measures per day	Number of days per week
a)	Cornflakes, Special K, Rice Krispies etc.	1 small bowl	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Bran Flakes, Sultana Bran, All Bran etc.	1 small bowl	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Shredded Wheat, Weetabix etc.	1 biscuit	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Coco Pops, Frosties, Sugar Puffs, Crunchy Nut Cornflakes etc.	1 small bowl	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Muesli (all types)	1 small bowl	1 2 3 4 5+	R M 1 2 3 4 5 6 7
f)	Porridge or Ready Brek	1 small bowl	1 2 3 4 5+	R M 1 2 3 4 5 6 7

3. Milk *(including milk on cereals and in drinks, but not in cooked foods)*

		Measure	Measures per day	Number of days per week
a)	Full fat milk	1/4 pint	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Semi-skimmed milk	1/4 pint	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Skimmed milk	1/4 pint	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Soya milk	1/4 pint	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Dried milk or creamer	1 teaspoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7

4. Cream and Yogurt

		Measure	Measures per day	Number of days per week
a)	Low fat yogurt (plain or fruit)	1 pot (125 ml)	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Full fat yogurt (e.g. Greek)	1 pot (125 ml)	1 2 3 4 5+	R M 1 2 3 4 5 6 7

Please make sure you have given an answer for every line before leaving this page

		Measure	Measures per day	Number of days per week
c)	Low calorie yogurt (plain or fruit)	1 pot (125 ml)	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Fromage frais (plain or fruit)	1 pot (125 ml)	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Cream (all types)	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7

5. Cheese

		Measure	Measures per day	Number of days per week
a)	Full fat hard cheese (e.g. Cheddar, Gruyere, Wensleydale, Gouda)	1 oz. (25g) or 1 slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Medium fat cheese (e.g. (Edam, Brie, Camembert, Feta, cheese spreads)	1 oz. (25g) or 1 slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Full fat cream cheese (e.g. Philadelphia, Boursin, Danish Blue)	1 oz. (25g) or 1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Low fat cheese (e.g. low fat cream cheese, low fat hard cheese)	1 oz. (25g) or 1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Cottage cheese (all types)	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7

SAMPLE

6. Eggs

		Measure	Measures per day	Number of days per week
a)	Boiled or poached eggs	1 egg	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Fried eggs	1 egg	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Scrambled eggs or omelette	1 egg	1 2 3 4 5+	R M 1 2 3 4 5 6 7

7. Meats *(Meat substitutes e.g. Quorn or soya are listed in section 10)*

		Measure	Measures per day	Number of days per week
a)	Mince or meat sauce (e.g. bolognese)	2 tablespoons	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Sausages (pork, beef or frankfurters)	1 sausage	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Burgers (beef, lamb, chicken or turkey)	1 burger	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Beef (roast, grilled, casseroled or fried)	2 tablespoons, 2 slices or 1 steak	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Pork or lamb (roast, grilled, casseroled or fried)	2 tablespoons, 2 slices or 1 chop	1 2 3 4 5+	R M 1 2 3 4 5 6 7

Please make sure you have given an answer for every line before leaving this page

		Measure	Measures per day	Number of days per week
f)	Chicken or turkey (roast, grilled, casseroled or fried)	1 wing or thigh, 1/2 breast or 2 slices	1 2 3 4 5+	R M 1 2 3 4 5 6 7
g)	Bacon or gammon	1 medium slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7
h)	Liver, liver sausage or liver pate	1 serving	1 2 3 4 5+	R M 1 2 3 4 5 6 7
i)	Haggis or black pudding	2 tablespoons or 1 slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7
j)	Meat or chicken pies, pasties or sausage roll	1 individual pie or 1 roll	1 2 3 4 5+	R M 1 2 3 4 5 6 7
k)	Cold meats (e.g. ham, corned beef, chicken roll)	1 slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7
l)	Salami or continental sausage	1 slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7

8. Fish

		Measure	Measures per day	Number of days per week
a)	Fish fingers	1 finger	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	White fish (e.g. haddock, cod, plaice or scampi) fried or cooked in batter	1 small fillet or 1 serving	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Grilled, poached or baked white fish	1 small fillet	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Smoked white fish	1 small fillet	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Fish cakes, fish pie	1 cake or 2 tablespoons	1 2 3 4 5+	R M 1 2 3 4 5 6 7
f)	Fried oily fish (e.g. salmon, herring, fresh tuna or mackerel)	1 small fillet	1 2 3 4 5+	R M 1 2 3 4 5 6 7
g)	Grilled, poached or baked oily fish	1 small fillet	1 2 3 4 5+	R M 1 2 3 4 5 6 7
h)	Smoked oily fish (kipper, mackerel or salmon)	1 small fillet or 1 slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7
i)	Tinned salmon	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
j)	Tinned tuna	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
k)	Sardines, pilchards or rollmop herrings	2 small fish or 1 large fish	1 2 3 4 5+	R M 1 2 3 4 5 6 7
l)	Prawns, crab etc.	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
m)	Mussels, oysters, cockles, scallops	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7

SAMPLE

Please make sure you have given an answer for every line before leaving this page

9. *Potatoes, Rice and Pasta*

		Measure	Measures per day	Number of days per week
a)	Boiled or baked potatoes	1 medium or 1/2 large	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Mashed potatoes	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Oven chips or potato waffles	1/4 plate or 1 waffle	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Home-cooked chips	1/4 plate	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Chips from a chip shop or restaurant	1/4 plate	1 2 3 4 5+	R M 1 2 3 4 5 6 7
f)	Roast or fried potatoes	1/4 plate	1 2 3 4 5+	R M 1 2 3 4 5 6 7
g)	White rice	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
h)	Brown rice	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
i)	Pasta (all types) or couscous	1/4 plate	1 2 3 4 5+	R M 1 2 3 4 5 6 7
j)	Noodles (all types)	1/4 plate or 1 pot	1 2 3 4 5+	R M 1 2 3 4 5 6 7

SAMPLE

10. *Savoury foods, Soups and Sauces*

		Measure	Measures per day	Number of days per week
a)	Pizza	1 slice or 1/2 a small pizza	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Quiche or savoury flan	1 slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Savoury pancakes	1 pancake	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Baked beans	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Nut roast, nut burgers or vegetable burgers	1 slice or burger	1 2 3 4 5+	R M 1 2 3 4 5 6 7
f)	Quorn products (all types)	1 tablespoon, slice or sausage	1 2 3 4 5+	R M 1 2 3 4 5 6 7
g)	Soya beans, TVP, Tofu or soya meat substitute	1 tablespoon or 1 sausage	1 2 3 4 5+	R M 1 2 3 4 5 6 7
h)	Other beans (kidney, butter, chick peas)	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
i)	Lentils (excluding soup)	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
j)	Soups (home-made)	1 small bowl	1 2 3 4 5+	R M 1 2 3 4 5 6 7
k)	Soups (tinned)	1 small bowl	1 2 3 4 5+	R M 1 2 3 4 5 6 7
l)	Soups (dried or instant)	1 small bowl or mug	1 2 3 4 5+	R M 1 2 3 4 5 6 7
m)	Gravy	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7

Please make sure you have given an answer for every line before leaving this page

		Measure	Measures per day	Number of days per week
n)	Tomato -based sauces (e.g. for pasta)	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
o)	Other savoury sauces (white, cheese etc.)	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
p)	Bottled sauces (e.g. ketchup)	1/2 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
q)	Mayonnaise or salad cream	1 teaspoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
r)	Oil & vinegar dressing	1 teaspoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
s)	Pickled vegetables or chutneys	1 teaspoon or 1 pickle	1 2 3 4 5+	R M 1 2 3 4 5 6 7

*11. **Vegetables** (including fresh, frozen and tinned vegetables)*

SAMPLE

		Measure	Measures per day	Number of days per week
a)	Mixed vegetable dishes (e.g. stir-fry, curry or bake)	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Tinned vegetables (all kinds)	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Peas or green beans	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Carrots	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Cabbage (all kinds)	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
f)	Brussels sprouts	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
g)	Broccoli	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
h)	Spinach or spring greens	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
i)	Leeks or courgettes	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
j)	Cauliflower, swede (neeps) or turnip	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
k)	Sweetcorn	1 tablespoon or 1 piece	1 2 3 4 5+	R M 1 2 3 4 5 6 7
l)	Onions	1 tablespoon or 1/2 onion	1 2 3 4 5+	R M 1 2 3 4 5 6 7
m)	Tomatoes	1/2 medium or 2 small	1 2 3 4 5+	R M 1 2 3 4 5 6 7
n)	Sweet peppers	1/4 pepper	1 2 3 4 5+	R M 1 2 3 4 5 6 7
o)	Other salad vegetables (lettuce, cucumber etc)	2 leaves or 4 slices	1 2 3 4 5+	R M 1 2 3 4 5 6 7
p)	Potato salad	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
q)	Coleslaw or other veg. salads in dressing	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7

Please make sure you have given an answer for every line before leaving this page

12. ***Fruit*** (including fresh, cooked, frozen and tinned fruits)

		Measure	Measures per day	Number of days per week
a)	Fresh fruit salad	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Tinned fruit (all kinds)	1 tablespoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Apples	1 fruit	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Bananas	1 fruit	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Oranges, satsumas or grapefruit	1 small or 1/2 large fruit	1 2 3 4 5+	R M 1 2 3 4 5 6 7
f)	Pears	1 fruit	1 2 3 4 5+	R M 1 2 3 4 5 6 7
g)	Peaches or nectarines	1 fruit	1 2 3 4 5+	R M 1 2 3 4 5 6 7
h)	Kiwi fruit	1 fruit	1 2 3 4 5+	R M 1 2 3 4 5 6 7
i)	Dried fruit (e.g. raisins, dates or figs)	1 tablespoon or 1 oz (25g)	1 2 3 4 5+	R M 1 2 3 4 5 6 7
j)	All other fruits (grapes, strawberries, melon etc)	1 tablespoon or 1 slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7

SAMPLE

13. ***Puddings***

		Measure	Measures per day	Number of days per week
a)	Milk-based puddings (e.g. rice, semolina)	1 small bowl	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Sponge puddings (e.g. (steamed, syrup, jam)	1 small bowl	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Gateau or cheesecake	1 slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Fruit-based puddings (e.g. pie, tart, crumble)	1 pie, 1 slice or 2 tablespoons	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Mousse, blancmange, trifle, meringue	2 tablespoons or 1 meringue	1 2 3 4 5+	R M 1 2 3 4 5 6 7
f)	Custard or other sweet sauces	2 tablespoons	1 2 3 4 5+	R M 1 2 3 4 5 6 7
g)	Wrapped ice creams (Cornetto, Solero, Magnum etc.)	1 ice cream	1 2 3 4 5+	R M 1 2 3 4 5 6 7
h)	Other ice cream (all flavours)	1 scoop or small tub	1 2 3 4 5+	R M 1 2 3 4 5 6 7

14. ***Chocolates, Sweets, Nuts and Crisps***

		Measure	Measures per day	Number of days per week
a)	Chocolate bars (e.g. Mars, Dairy Milk)	1 bar or 2 oz. (50g)	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Chocolate sweets, toffees or fudge	2 sweets	1 2 3 4 5+	R M 1 2 3 4 5 6 7

Please make sure you have given an answer for every line before leaving this page

		Measure	Measures per day	Number of days per week
c)	Boiled sweets, mints	2 sweets	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Fruit gums, pastilles, jellies or chewy sweets	2 sweets	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Salted nuts (peanuts, cashews etc.)	1 small packet or 1 oz. (25g)	1 2 3 4 5+	R M 1 2 3 4 5 6 7
f)	Unsalted nuts	1 small packet or 1 oz. (25g)	1 2 3 4 5+	R M 1 2 3 4 5 6 7
g)	Crisps	1 small bag (25g)	1 2 3 4 5+	R M 1 2 3 4 5 6 7
h)	Reduced fat crisps	1 small bag (25g)	1 2 3 4 5+	R M 1 2 3 4 5 6 7
i)	Other savoury snacks (Quavers, tortilla chips, popcorn etc.)	1 small bag	1 2 3 4 5+	R M 1 2 3 4 5 6 7

15. Biscuits

		Measure	Measures per day	Number of days per week
a)	Plain (e.g. Rich Tea, digestive)	1 biscuit	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Sweet (e.g. ginger, custard creams)	1 biscuit	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Shortbread	1 biscuit	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Chocolate coated biscuits	1 biscuit	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Savoury biscuits, (crackers, crispbreads)	1 biscuit	1 2 3 4 5+	R M 1 2 3 4 5 6 7
f)	Oatcakes	1 biscuit	1 2 3 4 5+	R M 1 2 3 4 5 6 7
g)	Cereal bars, flapjacks	1 bar or slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7

SAMPLE

16. Cakes

		Measure	Measures per day	Number of days per week
a)	Plain cakes (sponge, madeira, ginger etc.)	1 medium slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Sponge cakes with jam, cream or icing	1 medium slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Fruit cakes (all kinds)	1 medium slice	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Pastries, doughnuts or muffins	1 piece	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Pancakes or scones	1 pancake or scone	1 2 3 4 5+	R M 1 2 3 4 5 6 7

Please make sure you have given an answer for every line before leaving this page

17. *Spreads and Sugar*

		Measure	Measures per day	Number of days per week
a)	Jam, honey, or marmalade	1 teaspoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Yeast or meat extract (Marmite, Bovril etc.)	1/2 teaspoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Peanut butter or chocolate spread	1 teaspoon	1 2 3 4 5+	R M 1 2 3 4 5 6 7

d) How many teaspoons of table sugar did you use each day in drinks and on cereals or deserts? (If you did not use any table sugar, please enter 0). ☐☐

e) Did you use any butter, margarine or other fat spread or oil on bread? Yes ☐ No ☐

If yes, please give full details of the one or two types you used most (e.g. Asda Sunflower buttery spread).
If you did not spread any fat or oil on bread, please go straight on to question g.

____ Office Code ☐☐

____ Office Code ☐☐

SAMPLE

f) How much did you normally spread on one slice of bread? (**Please tick one answer).**
(an example of a thin layer is shown in the photograph on the front cover).

a scrape ☐ a thin layer ☐ a thick layer ☐

g) Did you use any fat or oil for home frying or cooking? Yes ☐ No ☐

If yes, please give full details of the one or two types you used most (e.g. Tesco Pure Vegetable Oil).
If you did not use any fat or oil for home frying or cooking, please go straight on to section 18.

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18. *Beverages and Soft Drinks*

		Measure	Measures per day	Number of days per week
a)	Tea (regular)	1 cup or mug	1 2 3 4 5+	R M 1 2 3 4 5 6 7
b)	Herbal, fruit or decaffeinated tea	1 cup or mug	1 2 3 4 5+	R M 1 2 3 4 5 6 7
c)	Instant coffee (regular)	1 cup or mug	1 2 3 4 5+	R M 1 2 3 4 5 6 7
d)	Decaffeinated coffee	1 cup or mug	1 2 3 4 5+	R M 1 2 3 4 5 6 7
e)	Filter, espresso or cappuccino coffee	1 cup or mug	1 2 3 4 5+	R M 1 2 3 4 5 6 7

Please make sure you have given an answer for every line before leaving this page

		Measure	Measures per day					Number of days per week								
f)	Pure fruit juice (orange, apple, etc.)	1/2 medium glass	1	2	3	4	5+	R	M	1	2	3	4	5	6	7
g)	Tomato juice	1/2 medium glass	1	2	3	4	5+	R	M	1	2	3	4	5	6	7
h)	Blackcurrant squash (e.g. Ribena)	1 medium glass	1	2	3	4	5+	R	M	1	2	3	4	5	6	7
i)	Other fruit squash	1 medium glass	1	2	3	4	5+	R	M	1	2	3	4	5	6	7
j)	Diet fizzy drinks (Cola, lemonade etc.)	1 can	1	2	3	4	5+	R	M	1	2	3	4	5	6	7
k)	Regular fizzy drinks	1 can	1	2	3	4	5+	R	M	1	2	3	4	5	6	7
l)	Mineral water	1 medium glass	1	2	3	4	5+	R	M	1	2	3	4	5	6	7
m)	Tap water (not in other drinks)	1 medium glass	1	2	3	4	5+	R	M	1	2	3	4	5	6	7
n)	Hot chocolate	1 cup or mug	1	2	3	4	5+	R	M	1	2	3	4	5	6	7
o)	Horlicks or Ovaltine	1 cup or mug	1	2	3	4	5+	R	M	1	2	3	4	5	6	7

SAMPLE

19. Alcoholic Drinks

Please estimate your average intake of alcohol over the last 2-3 months. If your intake varied from week to week, please try to give an overall estimate which allows for weeks with high or low intake. If you had less than one measure a week on average, please circle 0.

	Drink	Measure	Number of measures per week								
a)	Low alcohol lager or beer	1/2 pint	0	1-2	3-4	5-9	10-14	15-19	20-29	30-39	40+
b)	Dark beer (Export, bitter or stout)	1/2 pint	0	1-2	3-4	5-9	10-14	15-19	20-29	30-39	40+
c)	Light beer (lager or continental beers)	1/2 pint	0	1-2	3-4	5-9	10-14	15-19	20-29	30-39	40+
d)	White wine	1 wine glass	0	1-2	3-4	5-9	10-14	15-19	20-29	30-39	40+
e)	Red wine	1 wine glass	0	1-2	3-4	5-9	10-14	15-19	20-29	30-39	40+
f)	Sherry, port etc.	1 sherry glass	0	1-2	3-4	5-9	10-14	15-19	20-29	30-39	40+
g)	Spirits or liqueurs	1 pub measure	0	1-2	3-4	5-9	10-14	15-19	20-29	30-39	40+
h)	Alcopops (e.g. Bacardi Breezer)	1 bottle	0	1-2	3-4	5-9	10-14	15-19	20-29	30-39	40+
i)	Cider	1 bottle or 1/2 pint	0	1-2	3-4	5-9	10-14	15-19	20-29	30-39	40+

Please make sure you have given an answer for every line before leaving this page

20. *Other Foods and Drinks*

Please enter details of any foods or drinks which you had **more than once a week** in the last 2-3 months which you have not included in the questionnaire above. If you do not want to add any foods, please leave this section blank and go to section 21.

	Food description	Measure	Measures per day	Number of days per week
a)	____________________ ____________________	___________	1 2 3 4 5+	1 2 3 4 5 6 7
b)	____________________ ____________________	___________	1 2 3 4 5+	1 2 3 4 5 6 7
c)	____________________ ____________________	___________	1 2 3 4 5+	1 2 3 4 5 6 7
d)	____________________ ____________________	___________	1 2 3 4 5+	1 2 3 4 5 6 7

21. *Vitamin, Mineral and Food Supplements*

Please give details and brand name of any supplements (e.g. multivitamins, iron tablets, cod liver oil, evening primrose oil, Complan, wheatgerm, bran) which you took in the last 2-3 months.

	Supplement type	Measure	Measures per day	Number of days per week
a)	____________________	___________	1 2 3 4 5+	R M 1 2 3 4 5 6 7
Brand name and details___________________________				
b)	____________________	___________	1 2 3 4 5+	R M 1 2 3 4 5 6 7
Brand name and details___________________________				
c)	____________________	___________	1 2 3 4 5+	R M 1 2 3 4 5 6 7
Brand name and details___________________________				
d)	____________________	___________	1 2 3 4 5+	R M 1 2 3 4 5 6 7
Brand name and details___________________________				

SAMPLE

22. *Other Information*

Any other information or comments on your diet in the last 2-3 months

Date of completing the questionnaire ______________________________________

Thank-you very much for completing this questionnaire.

Please return it to the investigators as requested.

Appendix N
Instruction sheet for completing SCG-FFQ

ANTENATAL METABOLIC CLINIC DIET QUESTIONNAIRE

Notes:

- You are completing the questionnaire anonymously (without giving any names). Please do provide the information requested as truthfully as possible as the data will be used for research purposes by the Metabolic Antenatal Clinic.
- You will be asked to fill in the questionnaire twice throughout the pregnancy: once each during the 2^{nd} (week 12-24) and 3^{rd} trimester (week 25-40)
- It is preferable that you complete and return this questionnaire on the same day.

Instructions:
Please describe your food intake (frequency) over the **last 2-3 months.**

Please answer **every line** of the questionnaire.

Answer **two** questions in every line:

1) **AMOUNT:** How **much** of the food you had in a day you ate the food (*'Measures per day'*)
2) **FREQUENCY:** How many **days a week** you had the food (*'Number of days per week'*)

Measures per day

Describe your portion according to the measures given. *The given portion sizes are quite small so your usual portion may easily be two or more measures.*

Number of days per week

R = **Rarely or never** or less than once a month
No need to report 'Measures per day'

M = **Monthly** or more than once a month but less than once a week
Please report the 'Measures per day'

1-7 = **Average 1-6 days a week or everyday**
Please report the 'Measures per day'

Please select only **one answer** for each Measures and Frequency section. If you want to change your answer, just put a cross **(X)** through the wrong answer and circle the new one.

Please check if you have completed every line and not missed any answers before submitting.

Please also fill in the sections with blank spaces with your answers e.g. No.17) Spreads and Sugar, 20) Other Foods and Drinks (if applicable) and 21) Vitamin, Mineral and Food Supplements. Please write 'None' if you do not take any of these.

Please remember to return the questionnaire to the Research Midwife (Norma Forson) once you have finished.

Thank you for your time and effort!

Prepared by: NOR SHUKRI
Antenatal Metabolic Clinic
Tommy's the Baby Charity / University of Edinburgh

NUTRITION SURVEY

This is a survey, not a test. Your answers will help identify which dietary advice people find confusing.

It is important that you complete it by yourself.

Your answers will remain anonymous.

If you do not know the answer, mark "not sure" rather than guess.

Thank you for your time.

The first few items are about what advice you think experts are giving us.

1. **Do you think health experts recommend that people should be eating more, the same amount, or less of these foods?** *(tick one box per food)*

	More	Same	Less	Not Sure
Vegetables	☐	☐	☐	☐
Sugary foods	☐	☐	☐	☐
Meat	☐	☐	☐	☐
Starchy foods	☐	☐	☐	☐
Fatty foods	☐	☐	☐	☐
High fibre foods	☐	☐	☐	☐
Fruit	☐	☐	☐	☐
Salty foods	☐	☐	☐	☐

---

2. **How many servings of fruit and vegetables a day do you think experts are advising people to eat?** (One serving could be, for example, an apple or a handful of chopped carrots)

✍ ________

---

3. **Which fat do experts say is most important for people to cut down on?** *(tick one)*

(a) monounsaturated fat ☐
(b) polyunsaturated fat ☐
(c) saturated fat ☐
(d) not sure ☐

---

4. **What version of dairy foods do experts say people should eat?** *(tick one)*

(a) full fat ☐
(b) lower fat ☐
(c) mixture of full fat and lower fat ☐
(d) neither, dairy foods should be cut out ☐
(e) not sure ☐

Experts classify foods into groups. We are interested to see whether people are aware of what foods are in these groups.

1. **Do you think these are high or low in added sugar?** *(tick one box per food)*

	High	Low	Not Sure
Bananas			
Unflavoured yoghurt			
Ice-cream			
Orange squash			
Tomato ketchup			
Tinned fruit in natural juice			

---

2. **Do you think these are high or low in fat?** *(tick one box per food)*

	High	Low	Not Sure
Pasta (without sauce)			
Low fat spread			
Baked beans			
Luncheon meat			
Honey			
Scotch egg			
Nuts			
Bread			
Cottage cheese			
Polyunsaturated margarine			

3. **Do you think experts put these in the <u>starchy foods</u> group?** *(tick one box per food)*

	Yes	No	Not Sure
Cheese			
Pasta			
Butter			
Nuts			
Rice			
Porridge			

4. **Do you think these are <u>high or low in salt</u>?** *(tick one box per food)*

	High	Low	Not Sure
Sausages			
Pasta			
Kippers			
Red meat			
Frozen vegetables			
Cheese			

5. **Do you think these are <u>high or low in protein</u>?** *(tick one box per food)*

	High	Low	Not Sure
Chicken			
Cheese			
Fruit			
Baked beans			
Butter			
Cream			

6. **Do you think these are <u>high or low in fibre/roughage</u>?** *(tick one box per food)*

	High	Low	Not Sure
Cornflakes			
Bananas			
Eggs			
Red Meat			
Broccoli			
Nuts			
Fish			
Baked potatoes with skins			
Chicken			
Baked beans			

7. **Do you think these fatty foods are <u>high or low in saturated fat</u>?** *(tick one box per food)*

	High	Low	Not Sure
Mackerel			
Whole milk			
Olive oil			
Red meat			
Sunflower margarine			
Chocolate			

8. **Some foods contain a lot of fat but no cholesterol.**

(a) agree ❑
(b) disagree ❑
(c) not sure ❑

9. **Do you think experts call these <u>a healthy alternative to red meat</u>?** *(<u>tick one box per food</u>)*

	Yes	No	Not Sure
Liver pate			
Luncheon meat			
Baked beans			
Nuts			
Low fat cheese			
Quiche			

---

10. **A glass of unsweetened fruit juice counts as a helping of fruit.**
    (a) agree ❑
    (b) disagree ❑
    (c) not sure ❑

---

11. **Saturated fats are mainly found in:** *(tick one)*
    (a) vegetable oils ❑
    (b) dairy products ❑
    (c) both (a) and (b) ❑
    (d) not sure ❑

---

12. **Brown sugar is a healthy alternative to white sugar.**
    (a) agree ❑
    (b) disagree ❑
    (c) not sure ❑

---

13. **There is more protein in a glass of whole milk than in a glass of skimmed milk.**
    (a) agree ❑
    (b) disagree ❑
    (c) not sure ❑

---

14. **Polyunsaturated margarine contains less fat than butter.**
    (a) agree ❑
    (b) disagree ❑
    (c) not sure ❑

---

15. **Which of these breads contain the most vitamins and minerals?** *(tick one)*
    (a) white ❑
    (b) brown ❑
    (c) wholegrain ❑
    (d) not sure ❑

---

16. **Which do you think is higher in calories: butter or regular margarine?** *(tick one)*
    (a) butter ❑
    (b) regular margarine ❑
    (c) both the same ❑
    (d) not sure ❑

---

17. **A type of oil which contains mostly monounsaturated fat is:** *(tick one)*
    (a) coconut oil ❑
    (b) sunflower oil ❑
    (c) olive oil ❑
    (d) palm oil ❑
    (e) not sure ❑

---

18. **There is more calcium in a glass of whole milk than a glass of skimmed milk.**
    (a) agree ❑
    (b) disagree ❑
    (c) not sure ❑

---

19. **Which *one* of the following has the most calories for the same weight?** *(tick one)*
    (a) sugar ❑
    (b) starchy foods ❑
    (c) fibre/roughage ❑
    (d) fat ❑
    (e) not sure ❑

---

20. **Harder fats contain more:** *(tick one)*
    (a) monounsaturates ❑
    (b) polyunsaturates ❑
    (c) saturates ❑
    (d) not sure ❑

---

21. **Polyunsaturated fats are mainly found in:** *(tick one)*
    (a) vegetable oils ❑
    (b) dairy products ❑
    (c) both (a) and (b) ❑
    (d) not sure ❑

The next few items are about choosing foods.

Please answer what is being asked and not whether you like or dislike the food!

For example, suppose you were asked ...

"If a person wanted to cut down on fat, which cheese would be best to eat?"

(a) cheddar cheese
(b) camembert
(c) cream cheese
(d) cottage cheese

If you didn't *like* cottage cheese, but knew it was the right answer, you would still tick cottage cheese.

1. **Which would be the best choice for a low fat, high fibre snack?** *(tick one)*
   - (a) diet strawberry yoghurt ❑
   - (b) raisins ❑
   - (c) muesli bar ❑
   - (d) wholemeal crackers and cheddar cheese ❑

---

2. **Which would be the best choice for a low fat, high fibre light meal?** *(tick one)*
   - (a) grilled chicken ❑
   - (b) cheese on wholemeal toast ❑
   - (c) beans on wholemeal toast ❑
   - (d) quiche ❑

---

3. **Which kind of sandwich do you think is healthier?** *(tick one)*
   - (a) two <u>thick</u> slices of bread with a <u>thin</u> slice of cheddar cheese filling ❑
   - (b) two <u>thin</u> slices of bread with a <u>thick</u> slice of cheddar cheese filling ❑

---

4. **Many people eat spaghetti bolognese (pasta with a tomato and meat sauce). Which do you think is healthier?** *(tick one)*
   - (a) a <u>large amount</u> of pasta with a <u>little</u> sauce on top ❑
   - (b) a <u>small amount</u> of pasta with a <u>lot</u> of sauce on top ❑

---

5. **If a person wanted to reduce the amount of fat in their diet, which would be the best choice?** *(tick one)*
   - (a) steak, grilled ❑
   - (b) sausages, grilled ❑
   - (c) turkey, grilled ❑
   - (d) pork chop, grilled ❑

---

6. **If a person wanted to reduce the amount of fat in their diet, but didn't want to give up chips, which one would be the best choice?** *(tick one)*
   - (a) thick cut chips ❑
   - (b) thin cut chips ❑
   - (c) crinkle cut chips ❑

---

7. **If a person felt like something sweet, but was trying to cut down on sugar, which would be the best choice?** *(tick one)*
   - (a) honey on toast ❑
   - (b) a cereal snack bar ❑
   - (c) plain Digestive biscuit ❑
   - (d) banana with plain yoghurt ❑

---

8. **Which of these would be the healthiest pudding?** *(tick one)*
   - (a) baked apple ❑
   - (b) strawberry yoghurt ❑
   - (c) wholemeal crackers and cheddar cheese ❑
   - (d) carrot cake with cream cheese topping ❑

---

9. **Which cheese would be the best choice as a lower fat option?** *(tick one)*
   - (a) plain cream cheese ❑
   - (b) Edam ❑
   - (c) cheddar ❑
   - (d) Stilton ❑

---

10. **If a person wanted to reduce the amount of salt in their diet, which would be the best choice?** *(tick one)*
    - (a) ready made frozen shepherd's pie ❑
    - (b) gammon with pineapple ❑
    - (c) mushroom omelette ❑
    - (d) stir fry vegetables with soy sauce ❑

This section is about health problems or diseases.

1. **Are you aware of any major health problems or diseases that are related to a <u>low intake of fruit and vegetables</u>?**

   (a) yes ❑
   (b) no ❑
   (c) not sure ❑

   If yes, what diseases or health problems do you think are related to a low intake of fruit and vegetables?

   ✍ ________________________

   ____

   ____

2. **Are you aware of any major health problems or diseases that are related to a <u>low intake of fibre</u>?**

   (a) yes ❑
   (b) no ❑
   (c) not sure ❑

   If yes, what diseases or health problems do you think are related to a low intake of fibre?

   ✍ ________________________

   ____

   ____

3. **Are you aware of any major health problems or diseases that are related to <u>how much sugar</u> people eat?**

   (a) yes ❑
   (b) no ❑
   (c) not sure ❑

   If yes, what diseases or health problems do you think are related to sugar?

   ✍ ________________________

   ____

   ____

4. **Are you aware of any major health problems or diseases that are related to <u>how much salt</u> or sodium people eat?**

   (a) yes ❑
   (b) no ❑
   (c) not sure ❑

   If yes, what diseases or health problems do you think are related to salt?

   ✍ ________________________

   ____

   ____

5. **Are you aware of any major health problems or diseases that are related to the <u>amount of fat</u> people eat?**

   (a) yes ❑
   (b) no ❑
   (c) not sure ❑

   If yes, what diseases or health problems do you think are related to fat?

   ✍ ________________________

   ____

   ____

6. **Do you think these help to reduce the chances of getting certain kinds of cancer?** *<u>(answer each one)</u>*

	Yes	No	Not Sure
eating more fibre	❑	❑	❑
eating less sugar	❑	❑	❑
eating less fat	❑	❑	❑
eating less salt	❑	❑	❑
eating more fruit and vegetables	❑	❑	❑
eating less preservatives/additives	❑	❑	❑

7. **Do you think these help prevent heart disease?** *(answer each one)*

	Yes	No	Not Sure
eating more fibre	❑	❑	❑
eating less saturated fat	❑	❑	❑
eating less salt	❑	❑	❑
eating more fruit and vegetables	❑	❑	❑
eating less preservatives/additives	❑	❑	❑

8. **Which one of these is more likely to raise people's blood cholesterol level?** *(tick one)*
   - (a) antioxidants ❑
   - (b) polyunsaturated fats ❑
   - (c) saturated fats ❑
   - (d) cholesterol in the diet ❑
   - (e) not sure ❑

9. **Have you heard of antioxidant vitamins?**
   - (a) yes ❑
   - (b) no ❑

10. **If YES to question 9, do you think these are antioxidant vitamins?** *(answer each one)*

	Yes	No	Not Sure
Vitamin A	❑	❑	❑
B Complex Vitamins	❑	❑	❑
Vitamin C	❑	❑	❑
Vitamin D	❑	❑	❑
Vitamin E	❑	❑	❑
Vitamin K	❑	❑	❑

Finally, we would like to ask you a few questions about yourself.

1. **Are you male or female?**
   - (a) Male ❑
   - (b) Female ❑

2. **How old are you?**
   - (a) less than 18 ❑
   - (b) 18 - 24 ❑
   - (c) 25 - 34 ❑
   - (d) 35 - 44 ❑
   - (e) 45 - 54 ❑
   - (f) 55 - 64 ❑
   - (g) 65 - 74 ❑
   - (h) more than 75 ❑

3. **Are you:**
   - (a) single ❑
   - (b) married ❑
   - (c) living as married ❑
   - (d) separated ❑
   - (e) divorced ❑
   - (f) widowed ❑

4. **What is your ethnic origin?**
   - (a) White ❑
   - (b) Black Caribbean ❑
   - (c) Black African ❑
   - (d) Black other ❑
   - (e) Indian ❑
   - (f) Pakistani ❑
   - (g) Bangladeshi ❑
   - (h) Chinese ❑
   - (i) Asian - other ❑
     Please specify:
     ✍_______________
   - (j) Any other ethnic group ❑
     Please specify:
     ✍_______________

PLEASE TURN OVER

5. **Do you have any children?**
   - (a) No ☐
   - (b) 1 ☐
   - (c) 2 ☐
   - (d) 3 ☐
   - (e) 4 ☐
   - (f) more than 4 ☐

6. **Do you have any children, under 18 years, living with you?**
   - (a) Yes ☐
   - (b) No ☐

7. **What is the highest level of education you have completed?**
   - (a) primary school ☐
   - (b) secondary school ☐
   - (c) O levels / GCSEs ☐
   - (d) A levels ☐
   - (e) Technical or Trade Certificate ☐
   - (f) Diploma ☐
   - (g) Degree ☐
   - (h) Post-graduate degree ☐

8. **Do you have any health or nutrition related qualifications?**
   - (a) Yes ☐
     Please specify:
     ✍_______________
   - (b) No ☐

9. **What is your job?** *If you are not working now, what is your usual job? (please be specific).*

   ✍ ______________________

   ____

10. **If you have a partner, what is his/her job?** *If he/she is not working now, what is his/her usual job? (please be specific).*

    ✍ ______________________

    ____

11. **Are you currently:**
    - (a) employed full time ☐
    - (b) employed part time ☐
    - (c) unemployed ☐
    - (d) full time homemaker ☐
    - (e) retired ☐
    - (f) student ☐
    - (g) disabled or too ill to work ☐

12. **Are you on a special diet?**
    - (a) Yes ☐
      Please specify:
      ✍_______________
    - (b) No ☐

THE END

Thank you very much for your time.

If there are any comments you would like to make about this questionnaire, please do so below, they would be very welcome.

✍_________________________

____

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Appendix P
The Council on Nutrition and Appetite Questionnaire

COUNCIL ON NUTRITION & APPETITE QUESTIONNAIRE

Instruction: Please provide only ONE answer to each question

1. My appetite is
- a) very poor
- b) poor
- c) average
- d) good
- e) very good

2. When I eat
- a) I feel full after eating only a few mouthfuls
- b) I feel full after eating about one third of a meal
- c) I feel full after eating over half a meal
- d) I feel full after eating most of the meal
- e) I hardly ever feel full

3. I feel hungry
- a) rarely
- b) occasionally
- c) some of the time
- d) most of the time
- e) all of the time

4. Generally, food tastes
- a) very bad
- b) bad
- c) average
- d) good
- e) very good

5. Normally I eat
- a) less than one meal a day
- b) one meal a day
- c) two meals a day
- d) three meals a day
- e) more than three meals a day

6. I feel sick or nauseated when I eat
- a) most times
- b) often
- c) sometimes
- d) rarely
- e) never

\- End of Questionnaire –

Appendix Q
The Dutch Eating Behaviour Questionnaire

DUTCH EATING BEHAVIOUR QUESTIONNAIRE

Instructions: *Please answer all the questions.*
Please tick the box which closely represents your normal behaviour.

	Never	**Seldom**	**Sometimes**	**Often**	**Very often**
If you have put on weight do you eat less than you usually do?					
Do you try to eat less at mealtimes than you would like to eat?					
How often do you refuse food or drink offered because you are concerned about your weight?					
Do you watch exactly what you eat?					
Do you deliberately eat foods that are slimming?					
When you have eaten too much do you eat less than usual the following days?					
Do you deliberately eat less in order not to become heavier?					
How often do you try not to eat between meals because you are watching your weight?					
How often in the evening do you try not to eat because you are watching your weight?					
Do you take into account your weight with what you eat?					
Do you have the desire to eat when you are irritated?					
Do you have a desire to eat when you have nothing to do?					
Do you have a desire to eat when you are depressed or discouraged?					
Do you have a desire to eat when you are feeling lonely?					
Do you have a desire to eat when somebody lets you down?					
Do you have a desire to eat when you are cross?					

	Never	Seldom	Sometimes	Often	Very often
Do you have a desire to eat when you are approaching something unpleasant to happen?					
Do you get the desire to eat when you are anxious, worried or tense?					
Do you have a desire to eat when things are going against you or when things have gone wrong?					
Do you have a desire to eat when you are frightened?					
Do you have a desire to eat when you are disappointed?					
Do you have a desire to eat when you are emotionally upset?					
Do you have a desire to eat when you are bored or restless?					
If food tastes good to you do you eat more than usual?					
If food smells and looks good, do you eat more than usual?					
If you see or smell something delicious do you have a desire to eat it?					
If you have something delicious to eat, do you eat it straight away?					
If you walk past the baker do you have the desire to buy something delicious?					
If you walk past a snack bar or café, do you have the desire to buy something delicious?					
If you see others eating do you also have the desire to eat?					
Can you resist eating delicious foods?					
Do you eat more than usual, when you see others eating?					
When preparing a meal are you inclined to eat something?					

Thank you for completing this questionnaire!

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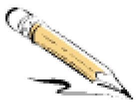
Pregnancy Physical Activity Questionnaire



Instructions:
Please use an ordinary No. 2 pencil. *Fill in the circles completely. The Question will be read by a machine so if you need to change your answer, erase the incorrect mark* ***completely***. *If you have comments, please write them on the back of the questionnaire.*

Example: During this trimester, when you are NOT at work, how much time do you usually spend:

E1. **Taking care of an older adult**

If you take care of your mom for 2 hours each day, then your answer should look like this... →

- ○ None
- ○ Less than 1/2 hour per day
- ○ 1/2 to almost 1 hour per day
- ○ 1 to almost 2 hours per day
- ● 2 to almost 3 hours per day
- ○ 3 or more hours per day

It is very important you tell us about yourself honestly. There are no right or wrong answers. We just want to know about the things you are doing during this trimester.

1. Today's Date: ☐☐ / ☐☐ / ☐☐☐☐ (Month / Day / Year)

2. What was the first day of your last period? ☐☐ / ☐☐ / ☐☐☐☐ (Month / Day / Year) ○ I don't know

3. When is your baby due? ☐☐ / ☐☐ / ☐☐☐☐ (Month / Day / Year) ○ I don't know

---

During this trimester, when you are NOT at work, how much time do you usually spend:

4. **Preparing meals (cook, set table, wash dishes)**
   - ○ None
   - ○ Less than 1/2 hour per day
   - ○ 1/2 to almost 1 hour per day
   - ○ 1 to almost 2 hours per day
   - ○ 2 to almost 3 hours per day
   - ○ 3 or more hours per day

5. **Dressing, bathing, feeding children while you are <u>sitting</u>**
   - ○ None
   - ○ Less than 1/2 hour per day
   - ○ 1/2 to almost 1 hour per day
   - ○ 1 to almost 2 hours per day
   - ○ 2 to almost 3 hours per day
   - ○ 3 or more hours per day

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During this trimester, when you are NOT at work, how much time do you usually spend:

6. **Dressing, bathing, feeding children while you are standing**
   - ○ None
   - ○ Less than 1/2 hour per day
   - ○ 1/2 to almost 1 hour per day
   - ○ 1 to almost 2 hours per day
   - ○ 2 to almost 3 hours per day
   - ○ 3 or more hours per day

7. **Playing with children while you are sitting or standing**
   - ○ None
   - ○ Less than 1/2 hour per day
   - ○ 1/2 to almost 1 hour per day
   - ○ 1 to almost 2 hours per day
   - ○ 2 to almost 3 hours per day
   - ○ 3 or more hours per day

8. **Playing with children while you are walking or running**
   - ○ None
   - ○ Less than 1/2 hour per day
   - ○ 1/2 to almost 1 hour per day
   - ○ 1 to almost 2 hours per day
   - ○ 2 to almost 3 hours per day
   - ○ 3 or more hours per day

9. **Carrying children**
   - ○ None
   - ○ Less than 1/2 hour per day
   - ○ 1/2 to almost 1 hour per day
   - ○ 1 to almost 2 hours per day
   - ○ 2 to almost 3 hours per day
   - ○ 3 or more hours per day

10. **Taking care of an older adult**
    - ○ None
    - ○ Less than 1/2 hour per day
    - ○ 1/2 to almost 1 hour per day
    - ○ 1 to almost 2 hours per day
    - ○ 2 to almost 3 hours per day
    - ○ 3 or more hours per day

11. **Sitting and using a computer or writing, while not at work**
    - ○ None
    - ○ Less than 1/2 hour per day
    - ○ 1/2 to almost 1 hour per day
    - ○ 1 to almost 2 hours per day
    - ○ 2 to almost 3 hours per day
    - ○ 3 or more hours per day

12. **Watching TV or a video**
    - ○ None
    - ○ Less than 1/2 hour per day
    - ○ 1/2 to almost 2 hours per day
    - ○ 2 to almost 4 hours per day
    - ○ 4 to almost 6 hours per day
    - ○ 6 or more hours per day

13. **Sitting and reading, talking, or on the phone, while not at work**
    - ○ None
    - ○ Less than 1/2 hour per day
    - ○ 1/2 to almost 2 hours per day
    - ○ 2 to almost 4 hours per day
    - ○ 4 to almost 6 hours per day
    - ○ 6 or more hours per day

14. **Playing with pets**
    - ○ None
    - ○ Less than 1/2 hour per day
    - ○ 1/2 to almost 1 hour per day
    - ○ 1 to almost 2 hours per day
    - ○ 2 to almost 3 hours per day
    - ○ 3 or more hours per day

15. **Light cleaning (make beds, laundry, iron, put things away)**
    - ○ None
    - ○ Less than 1/2 hour per day
    - ○ 1/2 to almost 1 hour per day
    - ○ 1 to almost 2 hours per day
    - ○ 2 to almost 3 hours per day
    - ○ 3 or more hours per day

16. **Shopping (for food, clothes, or other items)**
    - ○ None
    - ○ Less than 1/2 hour per day
    - ○ 1/2 to almost 1 hour per day
    - ○ 1 to almost 2 hours per day
    - ○ 2 to almost 3 hours per day
    - ○ 3 or more hours per day

During this trimester, when you are NOT at work, how much time do you usually spend:

17. **Heavier cleaning (vacuum. mop, sweep, wash windows)**

- ○ None
- ○ Less than 1/2 hour per week
- ○ 1/2 to almost 1 hour per week
- ○ 1 to almost 2 hours per week
- ○ 2 to almost 3 hours per week
- ○ 3 or more hours per week

18. **Mowing lawn while on a riding mower**
- ○ None
- ○ Less than 1/2 hour per week
- ○ 1/2 to almost 1 hour per week
- ○ 1 to almost 2 hours per week
- ○ 2 to almost 3 hours per week
- ○ 3 or more hours per week

19. **Mowing lawn using a walking mower, raking, gardening**
- ○ None
- ○ Less than 1/2 hour per week
- ○ 1/2 to almost 1 hour per week
- ○ 1 to almost 2 hours per week
- ○ 2 to almost 3 hours per week
- ○ 3 or more hours per week

Going Places...

During this trimester, how much time do you usually spend:

20. **Walking slowly to go places (such as to the bus, work, visiting)** ***Not for fun or exercise***
- ○ None
- ○ Less than 1/2 hour per day
- ○ 1/2 to almost 1 hour per day
- ○ 1 to almost 2 hours per day
- ○ 2 to almost 3 hours per day
- ○ 3 or more hours per day

21. **Walking quickly to go places (such as to the bus, work, or school)** ***Not for fun or exercise***
- ○ None
- ○ Less than 1/2 hour per day
- ○ 1/2 to almost 1 hour per day
- ○ 1 to almost 2 hours per day
- ○ 2 to almost 3 hours per day
- ○ 3 or more hours per day

22. **Driving or riding in a car or bus**
- ○ None
- ○ Less than 1/2 hour per day
- ○ 1/2 to almost 1 hour per day
- ○ 1 to almost 2 hours per day
- ○ 2 to almost 3 hours per day
- ○ 3 or more hours per day

For Fun or Exercise...

During this trimester, how much time do you usually spend:

23. **Walking slowly for fun or exercise**
- ○ None
- ○ Less than 1/2 hour per week
- ○ 1/2 to almost 1 hour per week
- ○ 1 to almost 2 hours per week
- ○ 2 to almost 3 hours per week
- ○ 3 or more hours per week

24. **Walking more quickly for fun or exercise**
- ○ None
- ○ Less than 1/2 hour per week
- ○ 1/2 to almost 1 hour per week
- ○ 1 to almost 2 hours per week
- ○ 2 to almost 3 hours per week
- ○ 3 or more hours per week

25. **Walking quickly up hills for fun or exercise**
- ○ None
- ○ Less than 1/2 hour per week
- ○ 1/2 to almost 1 hour per week
- ○ 1 to almost 2 hours per week
- ○ 2 to almost 3 hours per week
- ○ 3 or more hours per week

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UMASS

During this trimester, how much time do you usually spend:

26. **Jogging**
   - ○ None
   - ○ Less than 1/2 hour per week
   - ○ 1/2 to almost 1 hour per week
   - ○ 1 to almost 2 hours per week
   - ○ 2 to almost 3 hours per week
   - ○ 3 or more hours per week

27. **Prenatal exercise class**
   - ○ None
   - ○ Less than 1/2 hour per week
   - ○ 1/2 to almost 1 hour per week
   - ○ 1 to almost 2 hours per week
   - ○ 2 to almost 3 hours per week
   - ○ 3 or more hours per week

28. **Swimming**
   - ○ None
   - ○ Less than 1/2 hour per week
   - ○ 1/2 to almost 1 hour per week
   - ○ 1 to almost 2 hours per week
   - ○ 2 to almost 3 hours per week
   - ○ 3 or more hours per week

29. **Dancing**
   - ○ None
   - ○ Less than 1/2 hour per week
   - ○ 1/2 to almost 1 hour per week
   - ○ 1 to almost 2 hours per week
   - ○ 2 to almost 3 hours per week
   - ○ 3 or more hours per week

Doing other things for fun or exercise? Please tell us what they are.

30. ______________________
   Name of Activity
   - ○ None
   - ○ Less than 1/2 hour per week
   - ○ 1/2 to almost 1 hour per week
   - ○ 1 to almost 2 hours per week
   - ○ 2 to almost 3 hours per week
   - ○ 3 or more hours per week

31. ______________________
   Name of Activity
   - ○ None
   - ○ Less than 1/2 hour per week
   - ○ 1/2 to almost 1 hour per week
   - ○ 1 to almost 2 hours per week
   - ○ 2 to almost 3 hours per week
   - ○ 3 or more hours per week

Please fill out the next section if you work for wages, as a volunteer, or if you are a student. If you are a homemaker, out of work, or unable to work, you do not need to complete this last section.

At Work...

During this trimester, how much time do you usually spend:

32. **Sitting at working or in class**

   - ○ None
   - ○ Less than 1/2 hours per day
   - ○ 1/2 to almost 2 hours per day
   - ○ 2 to almost 4 hours per day
   - ○ 4 to almost 6 hours per day
   - ○ 6 or more hours per day

33. **Standing or slowly walking at work while carrying things (heavier than a 1 gallon milk jug)**
   - ○ None
   - ○ Less than 1/2 hour per day
   - ○ 1/2 to almost 2 hours per day
   - ○ 2 to almost 4 hours per day
   - ○ 4 to almost 6 hours per day
   - ○ 6 or more hours per day

34. **Standing or <u>slowly</u> walking at work <u>not</u> carrying anything**
   - ○ None
   - ○ Less than 1/2 hours per day
   - ○ 1/2 to almost 2 hours per day
   - ○ 2 to almost 4 hours per day
   - ○ 4 to almost 6 hours per day
   - ○ 6 or more hours per day

35. **Walking <u>quickly</u> at work while <u>carrying</u> things (heavier than a 1 gallon milk jug)**
   - ○ None
   - ○ Less than 1/2 hour per day
   - ○ 1/2 to almost 2 hours per day
   - ○ 2 to almost 4 hours per day
   - ○ 4 to almost 6 hours per day
   - ○ 6 or more hours per day

36. **Walking <u>quickly</u> at work <u>not</u> carrying anything**
   - ○ None
   - ○ Less than 1/2 hour per day
   - ○ 1/2 to almost 2 hours per day
   - ○ 2 to almost 4 hours per day
   - ○ 4 to almost 6 hours per day
   - ○ 6 or more hours per day

Thank You

Appendix S
Instruction sheet for wearing accelerometer

MEASUREMENT OF PHYSICAL ACTIVITY DURING PREGNANCY BY USING ACCELEROMETER

Introduction
An accelerometer is a small device which measures the energy that we use in doing daily physical activities. The device does not measure or record anything other than movement and energy expenditure.

Instructions for Participants

Please:

- Wear the *Actical* accelerometer for a 3-day period, comprising two working and one non-working days (or two weekdays and one weekend day if you are not working). Please ensure that you wear it for a complete 24 hours for each day.

- Wear the accelerometer on the wrist of your non-dominant hand (e.g. if you are right-handed then the Actical should be worn on your left wrist). The band should fit your wrist snugly for optimal measurement [refer illustration attached for proper placement of wristband].

- Wear the accelerometer during all waking and sleeping hours. Do not remove the device except for bathing or doing water-sports (please note times when removed).

- Carry out your normal daily routine as you would normally do.

- Record the times and duration when you remove the device in the form provided. This will be checked against the accelerometer output when you return the device to us.

- Keep the accelerometer safely (please do not misplace it!) as it is a very expensive device.

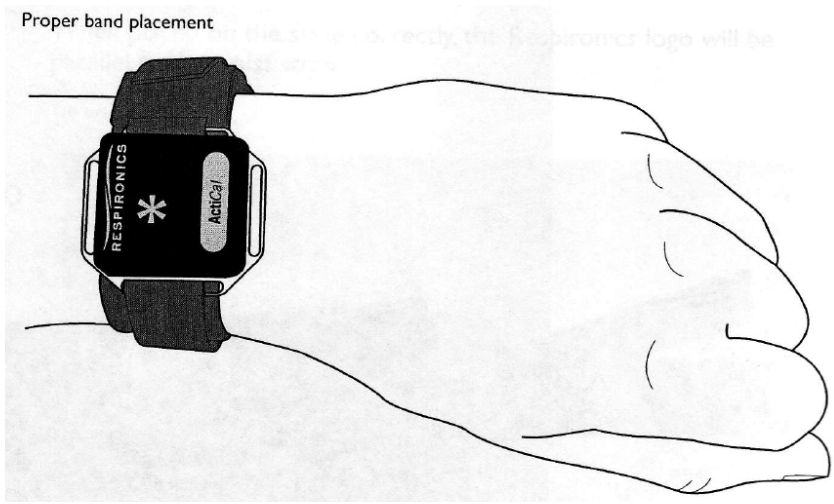
If you have any enquiries, please contact:

Nor Shukri
Endocrinology Unit (Room C3.02)
Centre for Cardiovascular Science
Queen's Medical Research Institute
University of Edinburgh
47, Little France Crescent
Edinburgh EH16 4TJ

Tel: 0131 242 6743 or 077 6874 8630 Email : s0793957@sms.ed.ac.uk

Thank you very much for taking part in this study.

Proper placement of the wrist band and Actical accelerometer



[Ilustration taken from Respironics Actical instruction manual]

***Note:**

Actical has been set to start recording data starting at 12.00 am on _ _/_ _/_ _

You should start wearing it before you go to bed on _________ night.

You could stop wearing it after 12.00 am on _________ morning.

(If you forget to wear it on the said time, please put it on as soon as you remember and continue wearing it for the next 72 hours)

DAY 1

Date	
Day	
Time begin	_ _:_ _ am / pm
Time end	_ _:_ _ am / pm (24 hours later)

Times when device is removed on this day				
No	From	Until	Duration (min/hrs)	Reason

DAY 2

Date	
Day	
Time begin	_ _:_ _ am / pm
Time end	_ _:_ _ am / pm (24 hours later)

Times when device is removed on this day				
No	From	Until	Duration (min/hrs)	Reason

DAY 3

Date	
Day	
Time begin	_ _:_ _ am / pm
Time end	_ _:_ _ am / pm (24 hours later)

Times when device is removed on this day				
No	From	Until	Duration (min/hrs)	Reason

Appendix T
Instruction sheet for participating in the DLW study

Tommy's

Antenatal Metabolic Clinic:

DOUBLY LABELLED WATER STUDY

COLLECTION OF URINE SAMPLES

Instructions:

- Collect one urine sample on **day 1, day 5, day 10 and day 14** after the doubly labelled water is consumed using the urine tubes provided.
- Try to collect sample at the same time each day e.g. second urine in the morning.
- Avoid first urine void of the day. Collect the sample half an hour later
- Before you collect the sample, check that you have the correctly labelled tubes. Fill in the time of the dosing.
- You should only fill the tube until half. Please do not fill it until full as this may cause the tube to crack when frozen or the lid to loosen which could lead to leaking when the sample is defrosted.
- Keep the samples double-bagged in ziplock plastic bags provided. The sample can be kept at room temperature if it is to be collected on the day itself. Otherwise (e.g. for weekend sample) you should place the tube in the container provided and keep them in your freezer until they are collected. Please remember to keep the tube upright during freezing.

Sampling Days:

Your sampling days are as follows. Please adhere to this as strictly as possible as this would greatly affect the results.

Sampling Day	Date	Day
Day 1		
Day 5		
Day 10		
Day 14		

Important Notes:

- The researcher will be texting you the day before and calling you on the sampling day to remind you to collect the sample.
- The researcher will pick up the sample from you on the sampling day. If this falls on a weekend day, the sample will be picked up on the next working day.

Thank you for your time and effort. If you have any enquiries, please contact the researcher:

Nor Shukri
Endocrinology Unit (Room C3.02)
Centre for Cardiovascular Science
The Queen's Medical Research Institute
47, Little France Crescent
Edinburgh EH16 4TJ

Tel: 0131 242 6743 or 077 6874 8630
Email: s0793957@sms.ed.ac.uk

Appendix U
List of macro- and micronutrients analyzed from the SCG-FFQ and food diary

Nutrient	**Units/day**
Total energy intake	kcal
Protein	g
Fat	g
Carbohydrate	g
Saturated fat	g
Monounsaturated fat	g
Polyunsaturated fat	g
Dietary cholesterol	g
Total sugar	g
Starch	g
Dietary fibre	g
Sodium	mg
Potassium	mg
Calcium	mg
Magnesium	mg
Phosphorus	mg
Iron	mg
Copper	mg
Zinc	mg
Chloride	mg
Manganese	mg
Selenium	µg
Iodine	µg
Vitamin A**	µg
Retinol	µg
Carotene equivalent	µg
Vitamin D	µg
Vitamin E	mg
Thiamine	mg
Riboflavin	mg
Niacin	mg
Potential niacin (from tryptophan)*	mg
Vitamin B6	mg
Vitamin B12	µg
Folic acid	µg/
Pantothenic acid	mg
Biotin	µg
Vitamin C	mg
Vitamin K*	µg
Alcohol	g

* Only available from FFQ analysis
**Only available from food diary analysis (using Windiets software)

Appendix V

Duration categories and intensity (MET values) assigned each question in PPAQ

Question	Duration		Intensity (MET Values)
	Category	Day/Week	
4		Daily x 7	2.5
5		Daily x 7	2.0
6		Daily x 7	3.0
7		Daily x 7	2.7
8		Daily x 7	4.0
9		Daily x 7	3.0
10		Daily x 7	4.0
11		Daily x 7	1.8
12		Daily x 7	1.0
13		Daily x 7	1.1
14		Daily x 7	3.2
15		Daily x 7	2.3
16		Daily x 7	2.3
17		Weekly	2.8
18		Weekly	2.8
19		Weekly	4.4
20		Daily x 7	2.5
21		Daily x 7	4.0
22		Daily x 7	1.5
23		Weekly	3.2
24		Weekly	4.6
25		Weekly	6.5
26		Weekly	7.0
27		Weekly	3.5
28		Weekly	6.0
29		Weekly	4.5
30		Weekly	Refer Compendium
31		Weekly	Refer Compendium
32		Daily x 7	1.6
33		Daily x 7	3.0
34		Daily x 7	2.2
35		Daily x 7	4.0
36		Daily x 7	3.3

Note:

0, 0.25, 0.75, 1.5, 2.5, 3.0 (Hours daily)

0, 0.25, 1.25, 3.0, 5.0, 6.0 (Hours daily)

0, 0.25, 0.75, 1.5, 2.5, 3.0 (Hours weekly)

Appendix W

Dietary Reference Intake equations (IOM, 2002) used in calculation of estimated energy requirement (EER)

Dietary Reference Intake	
Lean	Obese
EER equation for female adults (19 years and older) EER = 354 – [6.91 x Age (y)] + PAL x [9.36 x Weight (kg)] + [726 x Height (m)] Where PAL= 1.00 - Sedentary 2.00 - Low active 1.27 - Active	**EER equation for overweight and obese female adults (19 years and older)** EER = 448 – [7.95 x Age (y)] + PAL x [11.4 x Weight (kg)] + [619 x Height (m)] Where PAL= 1.00 - Sedentary 2.00 - Low active 1.27 - Active
Adjustment for pregnancy: 1^{st} trimester = adult EER + 0 + 0 2^{nd} trimester = adult EER + 160 (8kcal/week x 20 weeks) + 180 kcal 3^{rd} trimester = adult EER + 272 (8kcal/week x 34 weeks) + 180 kcal	