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FACULTY OF MEDICINE

HUMAN DEVELOPMENT AND HEALTH

MRC LIFECOURSE EPIDEMIOLOGY UNIT

**DIETARY FACTORS AND BLOOD MICRONUTRIENT LEVELS AS
RISK FACTORS FOR GESTATIONAL DIABETES MELLITUS IN INDIA
The BAngalore Nutrition Gestational diabetes LiFestyle Study
(BANGLES)**

by

ANVESHMA MAHENDRA

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Abstract

FACULTY OF MEDICINE, HUMAN DEVELOPMENT AND HEALTH,

MRC LIFECOURSE EPIDEMIOLOGY UNIT

DIETARY FACTORS AND BLOOD MICRONUTRIENT LEVELS AS RISK
FACTORS FOR GESTATIONAL DIABETES MELLITUS IN INDIA - The
BANGalore Nutrition Gestational diabetes LiFestyle Study (BANGLES)

By ANVESHA MAHENDRA

Indian women are at higher risk of gestational diabetes mellitus (GDM) than their Western counterparts. The current GDM prevalence in urban India is 20 – 25% of pregnancies. Observational evidence suggests a role for diet in GDM prevention, but data from India is sparse. My PhD project aimed to examine associations of peri-conceptional diet and early pregnancy blood micronutrient levels with GDM risk in Bangalore, India. In June 2016, I set up the BANGLES, a prospective observational study. Women (n=785) from low, middle and high-income groups were recruited at 5-16 weeks' gestation. The exposures were recalled peri-conceptional diet retrospectively assessed at recruitment, using a Food Frequency Questionnaire (FFQ), and blood micronutrient levels in early pregnancy: plasma folate, vitamin B12, vitamin D and serum ferritin. Diet exposure was represented by the frequency of intake of food groups, and diet patterns derived using Principal Components Analysis (PCA). The outcome was GDM assessed by a 75-gram Oral Glucose Tolerance Test (OGTT) at 24-28 weeks' gestation, and defined using WHO 2013 criteria. Associations between the exposures and GDM were analysed using multiple logistic regression, adjusting for potential confounders, with and without body mass index (BMI). Potential confounders adjusted for included the woman's age, gravidity, history of polycystic ovarian syndrome, family history of type 2 diabetes, urban/rural residence, nuclear/ joint family, physical activity, socio-economic status indicators and the use of synthetic nutrient supplements. GDM prevalence was 22%. Five distinct peri-conceptional diet patterns were derived in the PCA: 1) high-diversity, urban pattern, 2) rice-fried snacks-chicken-sweets pattern, 3) healthy, traditional vegetarian pattern, 4) snacks, sweets and takeaway pattern and 5) unpolished rice- vegetables-fish pattern. All except pattern 3 included a mixture of both healthy and unhealthy foods. There were no statistically significant associations between any of the food groups or diet patterns and GDM after adjusting for multiple testing. Higher BMI was a strong independent risk factor for GDM and adjusting for BMI weakened the diet pattern-GDM associations, suggesting that it may be a mediator of any diet pattern effects. Early pregnancy blood levels of folate, vitamins B12 and D were not associated with GDM risk. Women with low ferritin levels (<15 ng/ ml) had a lower GDM risk compared to women with normal serum ferritin levels (41-400 ng/ml; aOR: 0.39, 95% CI: 0.17, 0.90, p=0.02). Women who used iron and calcium+vitamin D tablets (almost always prescribed together) during early pregnancy had a higher GDM risk (aOR: 1.91, 95% CI: 1.21, 3.01, p=0.005). Women's physical activity (PA) during pregnancy was low overall, and not related to GDM. BANGLES is the first Indian prospective study to investigate associations of food groups, diet patterns, nutrient supplements and ferritin status with GDM. The findings support the existing global health recommendation to encourage women to attain a healthy pre-pregnancy BMI, which in turn requires a healthy diet and regular physical activity. My study did not identify specific foods or diet patterns associated with GDM that could form the basis of new recommendations. In future work I will explore healthy diet indices in relation to GDM in my data. The role of iron in the aetiology of GDM requires further research.

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Declaration of Authorship

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

**DIETARY FACTORS AND BLOOD MICRONUTRIENT LEVELS AS
RISK FACTORS FOR GESTATIONAL DIABETES MELLITUS IN INDIA
The BAngalore Nutrition Gestational diabetes LiFestyle Study (BANGLES)**

I confirm that:

- 1. This work was done wholly or mainly while in candidature for a research degree at this University;**
- 2. Where I have consulted the published work of others, this is always clearly attributed;**
- 3. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;**
- 4. I have acknowledged all main sources of help;**
- 5. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself**

Signed:

Date:

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List of Abbreviations

BANGLES - BAngalore **N**utrition **G**estational diabetes **L**if**E**style **S**tudy

FFQ - Food **F**requency **Q**uestionnaire

GDM - Gestational **D**iabetes **M**ellitus

IADPSG - International **A**ssociation of the **D**iabetes and **P**regnancy **S**tudy **G**roups

T2DM - Type 2 **D**iabetes **M**ellitus

WHO - World **H**ealth **O**rganisation

GCT - Glucose **C**hallenge **T**est

GTT/OGTT - Glucose **T**olerance **T**est/**O**ral **G**lucose **T**olerance **T**est

IDF - International **D**iabetes **F**ederation

PCOS - Poly **C**ystic **O**varian **S**yndrome

SES - Socio **E**conomic **S**tatus

SSB - Sugar **S**weetened **B**everages

BMI - Body **M**ass **I**ndex

PA - Physical **A**ctivity

OR - Odds **R**atio

RR - Relative **R**isk

SD - Standard **D**eviation

NFHS - National **H**ealth **F**amily **S**urvey

SLI - Standard of **L**iving **I**ndex

IPAQ - International **P**hysical **A**ctivity **Q**uestionnaire

PCA - Principal **C**omponent **A**nalysis

RDA - Recommended **D**ietary **A**llowances

PUFA - Poly **U**nsaturated **F**atty **A**cids

MUFA - Mono **U**nsaturated **F**atty **A**cids

Chapter 1

Introduction

1.1. Definition & diagnosis of gestational diabetes mellitus (GDM)

In 2010 the International Association of the Diabetes and Pregnancy Study Groups (IADPSG) Consensus Panel defined Gestational Diabetes Mellitus (GDM) as “any degree of glucose intolerance with onset or first recognition during pregnancy that is not clearly overt diabetes” (IADPSG, 2010). The previous, and still frequently used, definition “any degree of glucose intolerance with onset or first recognition during pregnancy” (Metzger & Coustan, 1998; American Diabetes Association [ADA] 2009 and Setji et al., 2005) was incomplete, because it did not differentiate between undiagnosed type 2 diabetes mellitus (T2DM) and GDM. T2DM during pregnancy is linked with a higher risk of complications and needs more intensive care and treatment than GDM (Ali & Dornhorst, 2011). Current consensus is that the term GDM be limited to hyperglycaemia detected during routine testing in pregnancy (generally between 24 - 28 weeks) which does not meet the standards of overt diabetes. Pregnant women with hyperglycaemia meeting the criteria of diagnosis of diabetes in the non-pregnant state as per the World Health Organisation (WHO) definition are classified as having diabetes in pregnancy (WHO, 2013).

The techniques of the Oral Glucose Tolerance Test (OGTT) and cut-off criteria differ between as well as within countries (McIntyre et al., 2015). The two most commonly used procedures for performing an OGTT are a 75 gram 2-hour OGTT and a 100 gram 3-hour OGTT. The most commonly applied diagnostic procedures and criteria for OGTT are presented in table 1.1. Most guidelines for diagnosing GDM recommend screening at 24-28 weeks of gestation for all pregnant women (IADPSG, 2010; Guideline Development Group of World Health Organization 2013) and early screening in the 1st trimester if risk factors are present, and that thresholds for overt diabetes criteria be applied (WHO, 2013). In

India there is huge diversity in the clinical surveillance, screening and diagnostic criteria used in practice among health professionals (WHO, 2013). A recent systematic review found that about ten studies reported a higher prevalence of GDM using the IADPSG criteria than the WHO 1999 criteria (Li et al., 2018).

Table 1.1: Recommendations for diagnostic method and thresholds for Gestational Diabetes Mellitus (adapted from Rani & Begum, 2016 & Meinilä, 2017)

Criteria	Approach	Fasting Glucose mmol/l	1-h Glucose mmol/l	2-h Glucose mmol/l	3-h Glucose mmol/l	Diagnosis
O'Sullivan & Mahan, 1964 (VWB)	Two-step	5.0	9.1	8.0	6.9	≥2 exceeding values
Carpenter & Coustan, 1982 (VS)	Two-step* (100 g load)	5.3	10	8.6	7.8	≥2 exceeding values
NDDG, 1979 (VP)	Two-step (100 g load)	5.8	10.6	9.2	8	≥2 exceeding values
WHO, 1999 (VP)	Two-step (75 g load)	≥7.0	-	7.8	-	≥1 exceeding value
IADPSG, 2010 (VP)	One-step (75 g load)	5.1	10	8.5	-	≥1 exceeding value
WHO 2013 (VP)	One-step (75 g load)	5.1	10	8.5	-	≥1 exceeding value
ADA 2010 (VP)	One-step (75 g load)	5.1	10	8.5	-	≥1 exceeding value
DIPSI, (VP) Seshiah V, 2005	One-step (75 g load)	-	-	7.8	-	≥1 exceeding value

1h: 1-hour; g – gram; VS - venous serum; VP - venous plasma; VWB - venous whole blood; NDDG: National Diabetes Data Group; WHO: World Health Organization; ADA: American Diabetes Association; IADPSG: International Association of Diabetes and Pregnancy Study Groups; DIPSI: Diabetes in Pregnancy Study Group of India *Two-step approach is initiated with screening by 50 g oral glucose test, exceeding the threshold of 7.8 mmol/l leads to step two, the 100 g OGTT.

1.2. Well established sequelae of Gestational Diabetes Mellitus

GDM is known to cause severe short and long-term consequences in both the mother and the baby. According to a landmark study – the Hyperglycaemia and Adverse Pregnancy Outcomes (HAPO) study, GDM results in a higher risk of short-term clinical problems in the mother, including obstructed labour and increased rates of instrumental and caesarean deliveries (Huang et al., 2015). GDM is the leading cause of 85% of adverse perinatal outcomes globally (Expert Committee on the Diagnosis and Classification of Diabetes Mellitus - ADA, 2003).

In the baby, maternal GDM increases the risk of foetal macrosomia (birthweight larger than 4.5 Kg) (Durnwald et al., 2004), shoulder dystocia, respiratory distress syndrome, neonatal hypoglycaemia, hyperbilirubinemia, hypercalcemia, congenital heart abnormalities like neonatal cardiac myopathies, and other malformations (Kozák-Bárány et al., 2004), risk of preterm birth (Billionnet et al., 2012) and foetal death (Lowe et al., 2012). In addition, doppler studies show that GDM may reduce blood flow to the umbilical artery leading to poor foetal growth (Reitter et al., 2011) (figure 1.1).

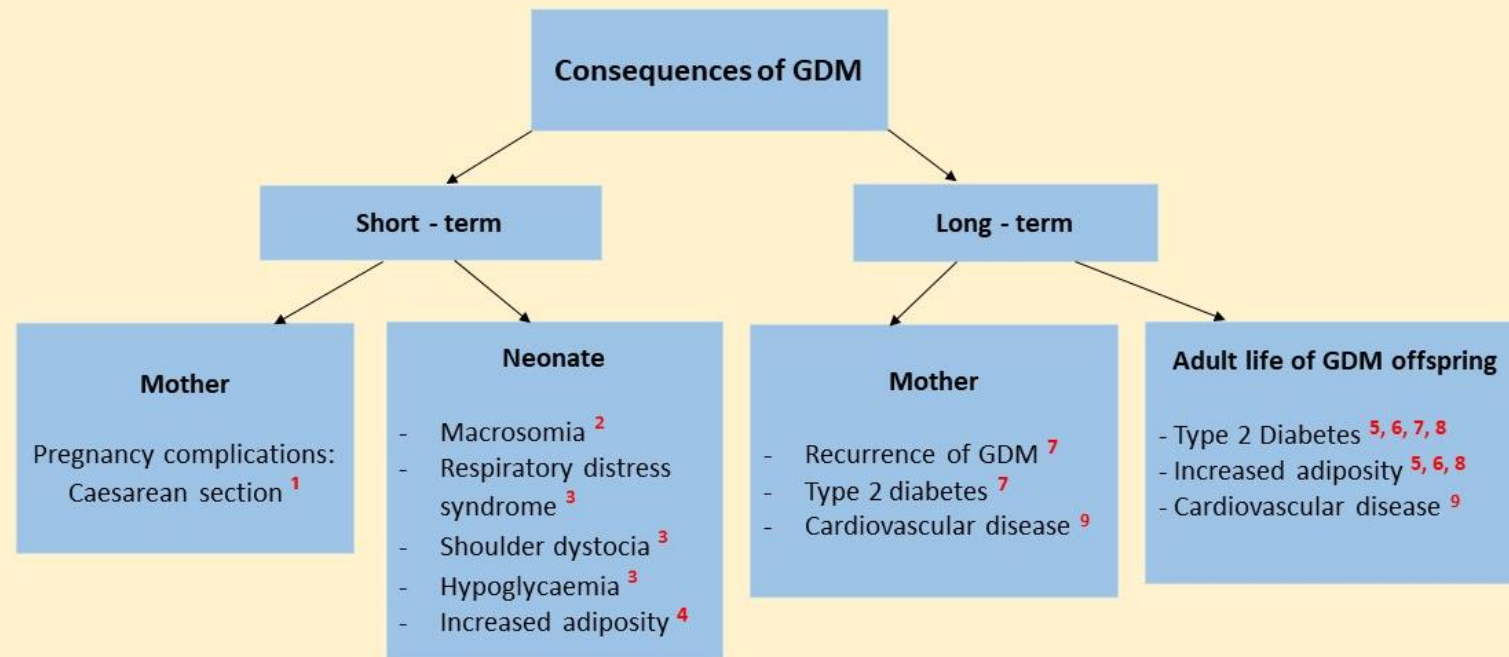
A long-term consequence of GDM is intrauterine programming of insulin resistance which contributes to increased adiposity in the offspring (Deierlein et al., 2011). The best example highlighting this phenomenon is the ground-breaking study in Pima Indians - the population has very high rates of adolescent and early adulthood diabetes because of intrauterine exposure to high sugars in pregnancy (Pettitt et al., 1993). A similar pattern can be seen among Alaskan natives where the prevalence of T2DM (28.3%) and gestational diabetes (7%) has been documented to be high (Naylor et al., 2003). In India, children (especially female) of GDM mothers had higher adiposity, glucose and insulin concentrations at 5 and 9 years of age (Krishnaveni et al., 2005). Interestingly, this effect was not found in children of fathers with diabetes, which suggests a programming effect due to the diabetic intrauterine environment. Intrauterine exposure to maternal GDM has long lasting effects on the epigenome of offspring, predisposing them to obesity (El Hajj et al., 2013) and cardiovascular disease throughout life (Sheiner et al., 2020). Some observational

evidence suggests an association between maternal GDM and offspring's poor psychomotor development (Sheiner et al., 2020). An Indian study found a higher cardiovascular response to stress in adolescent Indians exposed to maternal GDM during their in-utero development (Krishnaveni et al., 2015). Women with GDM have an increased risk of T2DM (Kim et al, 2002; Ben- Haroush et al, 2004; Albareda et al, 2003; Lauenborg et al, 2004). The WINGS (Women in India GDM Strategy) study predicted that more than 60% and 90% of GDM women will develop T2DM in the next 5 and 10 years respectively (International Diabetes Federation, 2019). Another study found that the incidence of T2DM in GDM women was 37% compared to 2% in non-GDM women (Krishnaveni et al., 2007). Global studies have reported that almost half of the proportion of diabetes (47.2%) in youth can be attributed to GDM in any population (Dabelea et al., 2008). Evidence from good-quality studies in different populations including the USA, Canada, Israel, and Sweden suggest that women with GDM may develop cardiovascular disease at a younger age (Sheiner et al., 2020). Some evidence also suggests that women with GDM are at an increased risk of renal failure, ophthalmic diseases (glaucoma and diabetic retinopathy) and breast and pancreatic malignancies (Sheiner et al., 2020). The complex interaction between environmental, genetic and perinatal factors puts both mothers with a history of GDM and their offspring at risk of diabetes and metabolic syndrome, thus setting up a vicious cycle of "diabetes begetting diabetes" (Barker, 1995; Lucas et al., 1999; Osgood et al., 2009 & Reece, 2004) (figure 1.1).

1.3. Glucose control in normal pregnancy and pathophysiology of Gestational Diabetes Mellitus

Pregnancy is a diabetogenic condition in which pregnancy hormones induce insulin resistance (Boyko et al., 1990). Insulin resistance is defined as the inability of a defined concentration of insulin to effect a predictable biological response of nutrient metabolism at the level of the target tissue (Einhorn et al., 2003), leading to a compensatory increase in insulin secretion. In pregnancy the reason for the physiological increase of insulin resistance is not clear. It is speculated

Figure 1.1: Well established sequelae of Gestational Diabetes Mellitus



¹ Huang et al., 2015; ² Durnwald et al., 2004; ³ Kozak Barany et al., 2004; ⁴ Deierlein et al., 2011; ⁵ Pettitt et al., 1993; ⁶ Naylor et al., 2003; ⁷ Krishnaveni et al., 2007, Kim et al., 2002, Ben Haroush et al., 2004, Albareda et al., 2003, Lauenborg et al., 2004 & Dabelea et al., 2008; ⁸ Barker et al., 1995, Lucas et al., 1999, Reece et al., 2004, Krishnaveni et al., 2005, El Hajj et al., 2013 & Osgood et al., 2009; ⁹ Sheiner et al., 2020.

that the increase in insulin resistance is nature's design to nourish the foetus, allowing glucose to flow to the foetus (Lain & Catalano, 2007). At the beginning of a normal pregnancy, insulin sensitivity is normal or increased (Catalano, 1994). But with the growth of the foeto-placental unit, and an increase in pregnancy hormones, insulin sensitivity in maternal tissues decreases (Newbern & Freemark, 2011). The reduction of insulin sensitivity starting at approximately 20-24 weeks of gestation is mediated by pregnancy and placental hormones including growth hormone (Barbour et al., 2007), progesterone (Ryan & Enns, 1988), prolactin, oestrogen, and placental lactogen (Di Cianni et al., 2003). These increase maternal beta-cell number and mass (Baeyens et al., 2016), resulting in a 200-250% increase in insulin secretion (Buchanan et al. 1990). Chronic insulin resistance, combined with deficient insulin secretion, indicative of deteriorating β -cell function in susceptible individuals, underlies the development of GDM (Buchanan & Xiang, 2005) (figure 1.2, page 7). The degree of insulin resistance during pregnancy may be increased by adiposity, genetic factors, diet and lifestyle (Di Cianni et al., 2003). The pathophysiology of GDM encompasses abnormalities of insulin-sensitive tissue. Postpartum studies of women with GDM have demonstrated defects in insulin secretory response and decreased insulin sensitivity (Catalano et al., 1986), indicating typical T2DM abnormalities in glucose metabolism. Beta-cell sensing of glucose is also abnormal and is manifested as an inadequate insulin response for a given degree of glycaemia.

1.4. Epidemiology of GDM

1.4.1. Prevalence of GDM globally and in India

In developed countries, by variable criteria, the prevalence of GDM ranges between 1.7% and 11.6% (Schneider et al., 2012). In the HAPO study of across 5 continents and 15 settings, applying IADPSG criteria, the overall frequency of GDM was 17.8%. The highest prevalence was in California and Ohio (USA), Singapore and Manchester (UK) and the lowest was in Barbados and Israel (Sacks et al. 2012) (table 1.2, page 8).

Figure 1.2: Development of Insulin Resistance (IR) and change in Insulin Secretion (IS) in normal pregnancy and development of GDM
(adapted & modified from Meinilä, 2017)

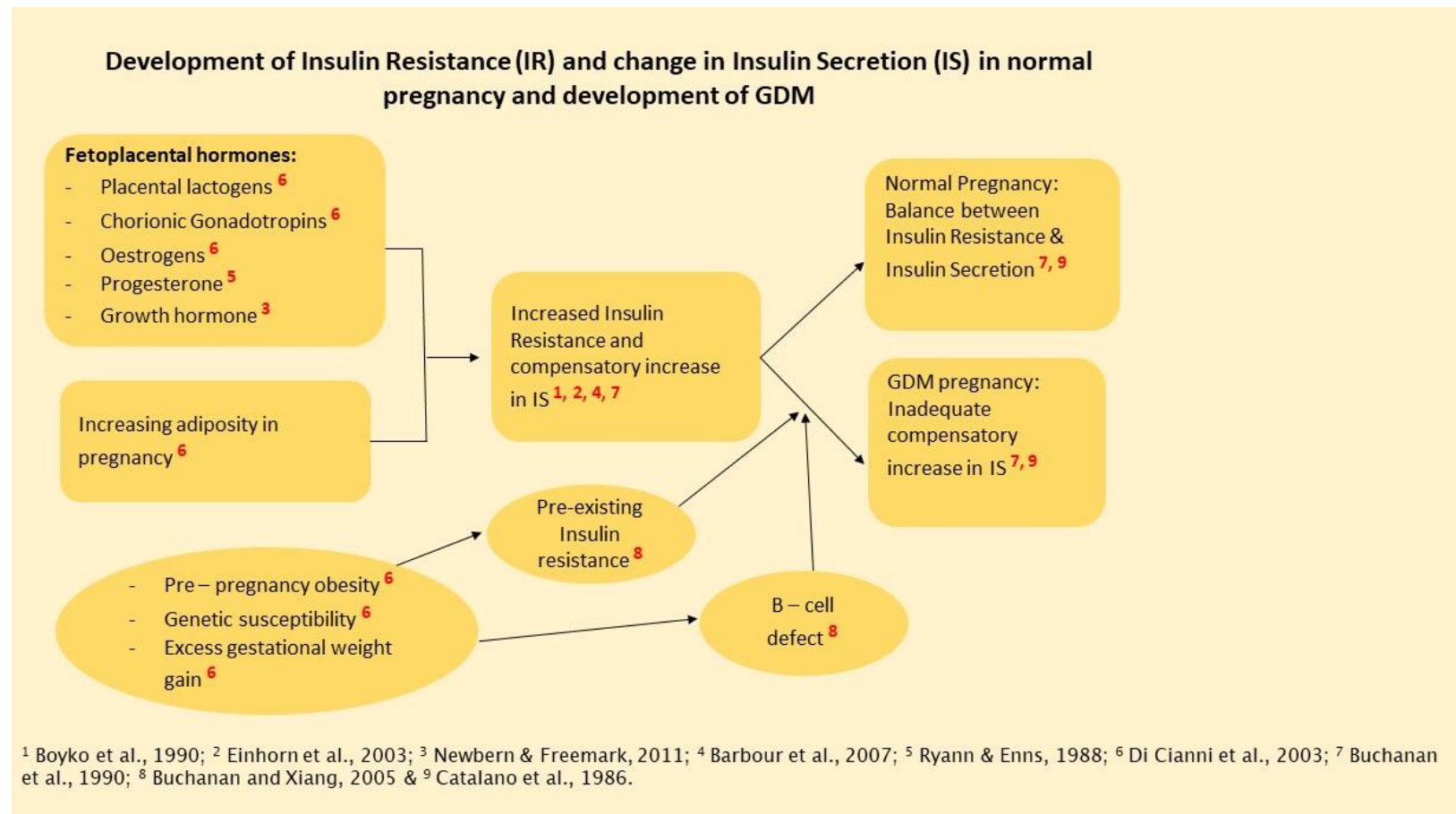


Table 1.2: Frequencies of GDM by centre in the HAPO study by IADPSG criteria (adapted from Sacks et al., 2012)

Center	Participants	Percentage of GDM
<i>HAPO overall</i>	<i>23,957</i>	<i>17.8</i>
<i>Bellflower, CA, USA</i>	<i>1,981</i>	<i>25.5</i>
<i>Singapore, Singapore</i>	<i>1,787</i>	<i>25.1</i>
<i>Cleveland, OH, USA</i>	<i>797</i>	<i>25.0</i>
<i>Manchester, U.K.</i>	<i>2,376</i>	<i>24.3</i>
<i>Bangkok, Thailand</i>	<i>2,499</i>	<i>23.0</i>
<i>Chicago, IL, USA</i>	<i>753</i>	<i>17.3</i>
<i>Belfast, U.K.</i>	<i>1,671</i>	<i>17.1</i>
<i>Toronto, Canada</i>	<i>2,028</i>	<i>15.5</i>
<i>Providence, RI, USA</i>	<i>757</i>	<i>15.5</i>
<i>Newcastle, Australia</i>	<i>668</i>	<i>15.3</i>
<i>Hong Kong, PRC</i>	<i>1,654</i>	<i>14.4</i>
<i>Brisbane, Australia</i>	<i>1,444</i>	<i>12.4</i>
<i>Bridgetown, Barbados</i>	<i>2,093</i>	<i>11.9</i>
<i>Petah-Tiqva, Israel</i>	<i>1,818</i>	<i>10.1</i>
<i>Beersheba, Israel</i>	<i>1,631</i>	<i>9.3</i>

Similar to the global differences, in India, there is wide variation in the prevalence of GDM across regions (Li et al., 2018) (figure 1.3, page 9). A recent systematic review including 64 studies reported 90 prevalence estimates across India, from 0 to 41.9%, published from 1988 to 2016. Low prevalence regions were Assam (3%), Manipur (0-1%), Jammu & Kashmir (4-11%) and Maharashtra (0.5-9%). Regions with a high prevalence were Andhra Pradesh (17- 22%) and Uttar Pradesh (13-42%) (Li et al., 2018). In some studies, prevalence rates have been as high as 35% (Punjab) and 41% (Lucknow) (Mithal et al., 2015). Estimating GDM prevalence is challenging because of differences in populations, geographical areas, screening methods, gestational ages of screening, diagnostic criteria, health care systems, socio-economic status, dietary habits and lifestyles (Li et al., 2018). Nine studies in rural areas identified a prevalence of 0.5-13.9% whereas twelve studies in urban areas reported a larger range of 0.5-41.9% (Li et al., 2018). These differences make it difficult to draw conclusions about trends over the last two decades. Another important reason for these varied prevalence estimates are the different options for accessing healthcare in India, including public and private hospital systems (figure 1.4, page 10). Public hospitals controlled by the Government provide free but basic facilities and mainly cater to women from lower income groups. The private system can be divided into profit and non-profit centres. Multispecialty and speciality hospitals, nursing homes and private

clinics come under the profit centres and charitable hospitals and non-governmental clinics come under the non-profit sector. The profit sector hospitals are luxurious, have advanced medical facilities that are expensive and cater to women from higher income groups. A woman from a low-income group will not seek medical care in a private hospital and vice versa. These differences pose challenges in getting a representative sample for estimating average GDM prevalence (Ramadas, 2014).

Figure 1.3: Median prevalence estimates by state/territory. Number of studies for each state shown on the map in bold (figure adapted from Li, et al., 2018)

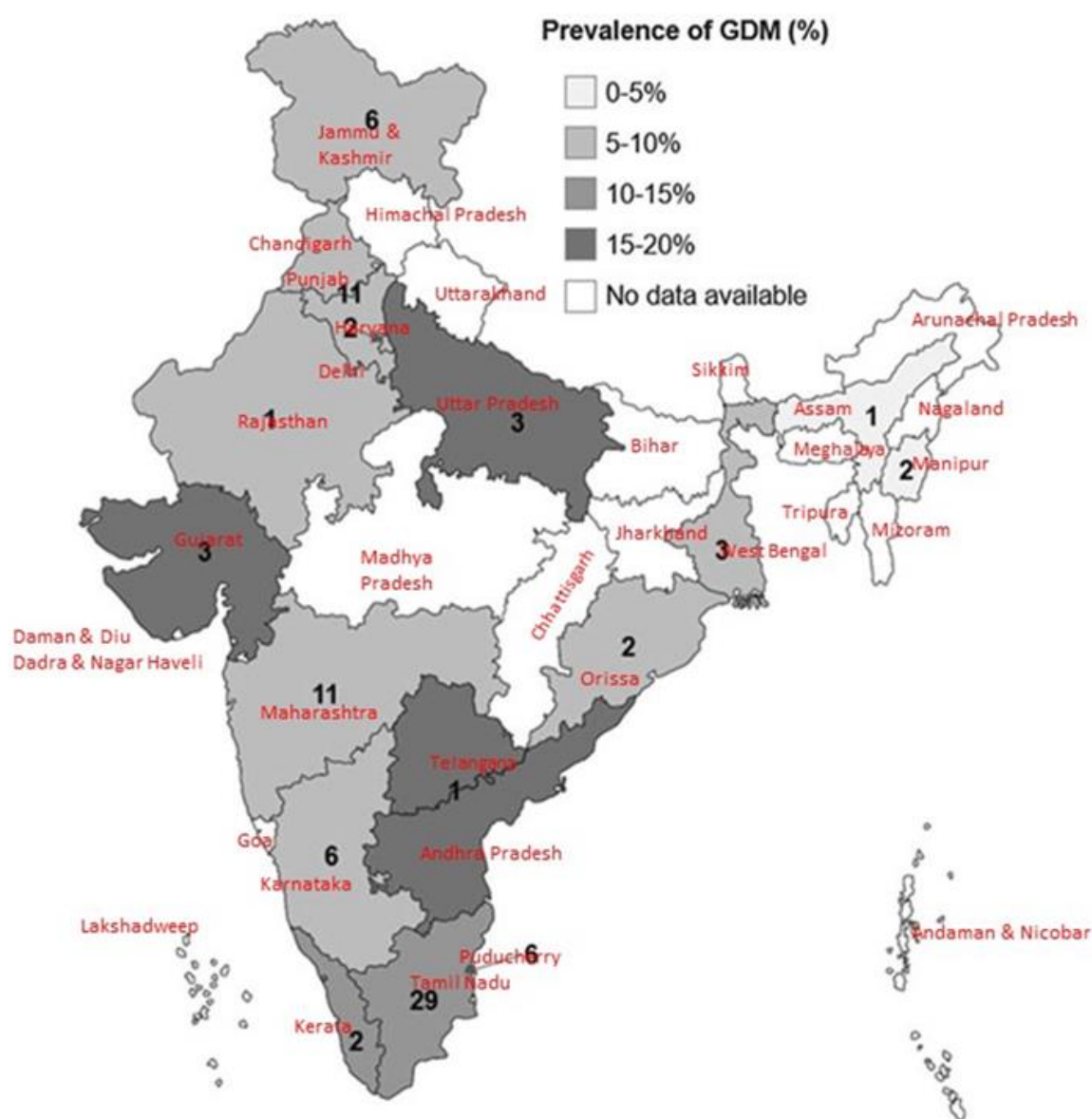
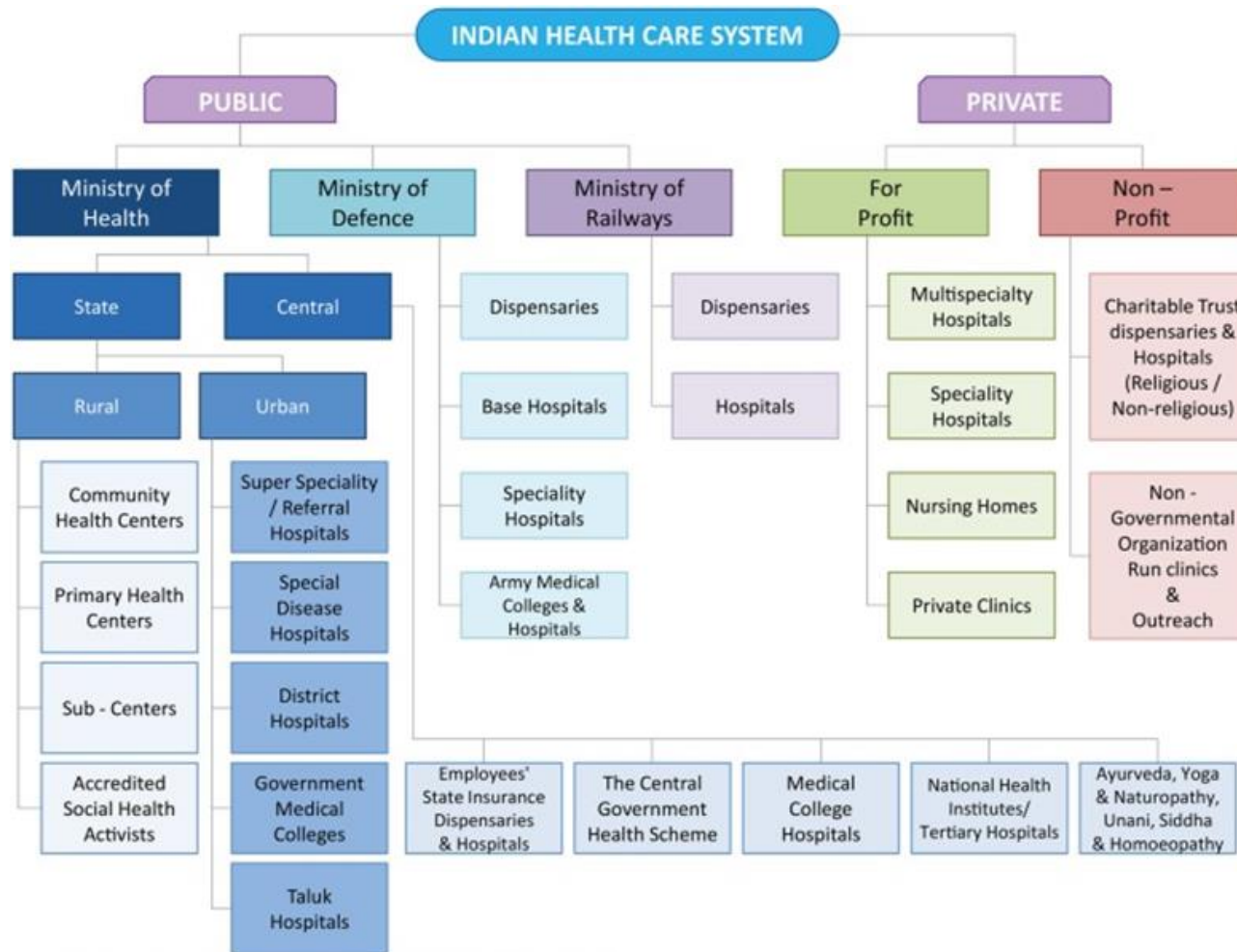


Figure 1.4: Levels of Healthcare systems in India (adapted from Ramadas, 2014)



1.4.2. Risk factors for GDM

Table 1.3 depicts major non-modifiable and modifiable risk factors for GDM identified to date, and their levels of evidence.

Modifiable risk factors are important in terms of understanding prevention of GDM, and diet and physical activity are important modifiable risk factors as they are both determinants of adiposity, an established risk factor (Tobias et al. 2012). Observational and interventional evidence indicates that diet could have a role in GDM prevention (Tobias et al. 2012, Schoenaker et al. 2015, He et al., 2015, Tryggvadottir et al., 2016 & Sahariah et al., 2016). High intakes of vegetables, fruits, and wholegrain carbohydrates and low consumption of high-fat/high-sugar foods and red and processed meat are associated with a lower risk of GDM, independent of adiposity (He et al., 2015, Tryggvadottir et al., 2016). The next section explores the role of diet in detail.

Table 1.3: Risk factors for GDM

Non – modifiable	Modifiable
Increasing maternal age ¹	Diet ¹²
Family history of T2DM among first degree relatives ²	High body mass Index ¹³
South Asian ethnicity ³	High waist to Hip Ratio ¹⁴
Gravidity >3 ⁴	High gestational weight gain ¹⁵
Polycystic Ovarian Syndrome (PCOS) ⁵	Low physical activity / sedentary lifestyle ¹⁶
Previous history of spontaneous abortions or still births ⁶	Less sleep duration ¹⁷
History of Macrosomia ⁷	High stress ¹⁸
Early menarche ⁸	Smoking ¹⁹
Maternal high and low birth weight ⁹	Socio Economic Status ²⁰
Maternal short stature ¹⁰	
Genetics ¹¹	
*Established risk factor	
*Moderate strength of evidence	
*Weak evidence	

¹ Seshiah et al., 2008; Xiong et al., 2001; Hill et al., 2005; Tripathi et al., 2011; Arora et al., 2015; Bhavadharini et al., 2016 & Rajput et al., 2013 ² Seshiah et al., 2008; Solomon et al., 1997; Hill et al., 2005; Tripathi et al., 2012; Rajput et al., 2014, Arora et al., 2015 & Bhavadharini et al., 2016 ³ Retnakaran et al., 2007 ⁴ Seshiah et al., 2008 & Rajput et al., 2014 ⁵ Wang et al., 2013, Joham et al., 2014, Qin et al., 2013 & Reyes-Munoz et al., 2012 ⁶ Jain et al., 2016; Tripathi et al., 2012 & Dahiya et al., 2014 ⁷ Dahiya et al., 2014, Kalra et al., 2013 ⁸ Shen et al., 2017 ⁹ Seghieri et al., 2002 ¹⁰ Seghieri et al., 2002 ¹¹ Robitaille and Grant, 2008 ¹² Sahariah et al., 2016; Tobias et al. 2012; Schoenaker et al. 2016a; He et al., 2015 & Tryggvadottir et al., 2016 ¹³ Mandal et al., 2011; Gopalakrishnan et al., 2015; Hill et al., 2005; Kulkarni et al., 2007; Madhavan et al., 2008; Ramachandran et al., 2008; Ramachandran et al., 1997 & Seshiah et al., 2008 ¹⁴ Madhavan et al., 2008 ¹⁵ Gutaj et al., 2011; Gibson et al., 2012 & Arjmandi et al., 2012 ¹⁶ Iqbal et al., 2007 ¹⁷ Facco et al., 2010 ¹⁸ Lydon et al., 2012 ¹⁹ Terry et al., 2003; ²⁰ Mithal et al., 2015; Gopalakrishnan et al., 2015; Hill et al., 2005; Mohan & Chandrakumar, 2016 & Kragelund et al., 2016

1.5. Diet and GDM prevention

1.5.1. Different approaches for the study of dietary exposures

In understanding the nutrition-disease relationship, diet can be approached by a single-nutrient analysis or by individual food groups or by a more comprehensive whole diet approach (Willett & Mc. Cullough, 2008). Studies examining single nutrients and individual food groups may be important for understanding physiological mechanisms (Sandström, 2001). However, they are limited by the fact that, in real life we eat a combination of different foods containing many nutrients - eaten together as part of the whole diet or a diet pattern (Hu, 2002). Diet patterns are defined as the quantities, proportions, variety or combinations of different foods and beverages in diets, and the frequency with which they are habitually consumed (Hu, 2002). The diet pattern approach takes into account the food matrix effect (specific effects and interactions of different foods and nutrients (Hu, 2002). The knowledge derived from studying diet patterns has the potential to inform public health recommendations, design interventions to improve women's diets and study the effect on health outcomes (Willett & Mc. Cullough, 2008). Methods to study whole diets include data-driven dietary pattern analysis, performed by factor analysis, principal component analysis, or reduced rank regression (Hu, 2002; Schulze et al., 2003), or a researcher-driven analysis using dietary indices (Arvaniti & Panagiotakos 2008).

Observational evidence from studies of dietary exposures as nutrients, food groups and diet patterns, suggests a role for diet before and

during pregnancy to prevent GDM. The next sections 1.5.2, 1.5.3 and 1.5.4 will review this evidence (systematic literature search strategy in Appendix A, page 285). Section 1.5.5 will describe diet interventions to prevent GDM and 1.5.6 will describe dietary prevention of T2DM.

1.5.2. Associations between nutrients and GDM risk

Observational studies have shown that the intake of total fat, cholesterol, heme iron, dietary fibre and protein were associated with GDM risk (table 1.4, pages 17 - 24).

Fat: In the Pregnancy, Infection, and Nutrition Study in the USA, total fat intake during pregnancy was significantly greater among women with GDM. Also, addition modelling of this observational data showed that theoretically substituting carbohydrates with fat was associated with a higher risk (Relative Risk [RR]: 1.10, 95% CI: 1.02-1.12) (Saldana et al., 2004). Similar modelling of data from the US Nurses' Health Study II (NHS II), suggested that theoretically replacing 5% of energy from carbohydrates with total fat increased the risk (RR: 1.13, 95% CI: 1.08, 1.18) (Bowers et al., 2012). Both studies reported carbohydrate intake was within daily limits of 45–65% of total energy intake, while total fat intake exceeded the recommendation of 20–35% of total energy intake (Schoenaker et al., 2015). There was no association between fat subtypes (saturated, monounsaturated, polyunsaturated, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) and GDM risk (Bowers et al., 2012; Radesky et al., 2008 & Mohanty et al., 2016). Higher omega-3 fatty acid intake among US women was positively associated with GDM risk (OR: 1.11, 95% CI: 1.02, 1.22 per increase of 300 mg per day (Radesky et al., 2008).

Cholesterol: A cholesterol intake of ~300 mg/day or more was associated with a higher GDM risk in the Omega and Alpha studies in the USA. In the Omega study, the RR for >294 versus <151 mg/day was 2.35 (95% CI: 1.35, 4.09) and in the Alpha study, the OR was 2.94 (95% CI: 1.14, 7.60) (Qiu et al., 2011a). In the NHS II, the highest quintile of median cholesterol intake (>310 mg/day) compared to lowest (<167 mg/day) was associated with a higher risk (RR: 1.45 [95% CI: 1.11, 1.89]) (Bowers et al., 2012).

Heme Iron: A higher heme intake before and during pregnancy was associated with higher risk in two prospective cohorts in the USA, after adjusting for intake of saturated fat, cholesterol and red meat. A daily increase of 1 mg and 0.5 mg in intake of heme iron was associated with an increased risk (RR: 1.51 [95% CI: 0.99, 2.36] and RR: 1.22 [1.10, 1.36]) respectively (Qiu et al., 2011b & Bowers et al., 2011).

Dietary fibre: In the same US study, a 5-gram and 10-gram higher intake of cereal or fruit fibre before pregnancy was associated with a 23 percent (95% CI: 9-36) and 26 percent (95% CI: 9-49) lower risk respectively (Zhang et al., 2006b).

Protein: Total protein intake was not associated with GDM risk (Saldana et al., 2004) in the USA. However, in the NHS II in the USA, women who consumed more animal protein from red meat had a higher risk (RR: 1.49, 95% CI: 1.03, 2.17), and a higher intake of vegetable protein (mostly from nuts) was associated with a lower risk (RR: 0.69, 95% CI: 0.50, 0.97). Modelling suggested that, theoretically, replacement of red meat with poultry, fish, nuts, or legumes was associated with a lower GDM risk (Bao et al., 2013). Higher total and animal protein intake was associated with a higher risk in China (Liang et al., 2018) and Singapore (Pang et al., 2017), with the latter study also reporting higher risk with higher vegetable and animal protein intake.

1.5.3. Association between foods, food groups and GDM risk

Higher intake of red and processed meat, egg, sugar sweetened beverages, fried and fast foods, potato, refined cereals and cookies and pastries were associated with a higher risk, while higher intake of nuts, legumes, wholegrain cereals, fruits, vegetables and moderate coffee have been associated with lower risk (table 1.4).

Red and processed meat: Higher pre-pregnancy intake of red and processed meat (including beef, lamb, pork, hamburger, bacon, beef hot dogs and sausages, salami and bologna) were significantly associated with increased risk in the NHS II. For highest versus lowest quintiles of red meat intake the OR was 2.05, 95% CI: 1.55, 2.73 (Bao et al., 2013). An increase of one daily serving of red and processed meat was associated with an increased risk (RR: 1.61, 95% CI: 1.25, 2.07 &

RR:1.64, 95% CI: 1.13, 2.38 for red and processed meat respectively) (Zhang et al., 2006a). The Alpha study showed a higher intake of red and processed meat during pregnancy among GDM women than controls (1.07 vs. 0.81 servings/day among GDM and control women, $p < 0.001$) (Qiu et al., 2011a). Similar findings were reported in Spain (Marí-Sanchis et al., 2018).

Eggs: The Alpha and Omega studies reported that consumption of ≥ 7 eggs per week, compared to less, during early pregnancy was associated with a higher risk, (Alpha, OR: 2.65, 95% CI: 1.48, 4.72; Omega, RR: 1.77, 95% CI: 1.19, 2.63). Both studies indicated a dose-response association for increasing egg consumption and higher risk (Qiu et al., 2011a).

Sugar Sweetened Beverages (SSBs): Women who consumed ≥ 5 / week versus < 1 /month versus had a 22% higher GDM risk, RR: 1.22, 95% CI: 1.01, 1.47, in the NHS II (Chen et al., 2009). Fewer than 4 servings of sweetened juices versus more than 4 per week was associated with a lower GDM risk in Spain (OR: 0.77, 95% CI: 0.62, 0.95, $p < 0.017$) (Ruiz-Gracia et al., 2016).

Fried & fast foods: In the USA, women who consumed fried foods pre-pregnancy, mainly away from home, had a higher risk, RR (95% CI) for 1–3, 4–6, ≥ 7 times/week versus < 1 time/ week were 1.13 (0.97, 1.32), 1.31 (1.08, 1.59) and 2.18 (1.53, 3.09) respectively, p for trend: 0.01 (Bao et al., 2014). Similar findings relating to fast food and French fries were reported among Spanish and Iranian women (Dominguez et al., 2014 & Lamyian et al., 2017).

Potato: Higher intake of potato was positively associated with GDM risk and theoretical modelling showed that replacing 2 weekly servings of potato with vegetables, legumes and wholegrains was associated with a 9-12 percent lower risk among American women (Bao et al., 2016). Another study in Iran found no association between potato intake and GDM (Goshtasebi et al., 2018).

Legumes & nuts: In Spain, women who consumed nuts > 3 times per week versus less had a lower risk (OR: 0.59, 95% CI: 0.39, 0.91) (Ruiz-Gracia et al., 2016). Intake of at least three servings of legumes per

week was associated with a lower risk (OR: 0.38, 95% CI: 0.19–0.74) among Iranian women (Goshtasebi et al., 2018).

Fruits & vegetables: Iranian women who consumed more than 5 daily servings of fruits & vegetables had a lower risk than those who had 2 daily servings (OR: 0.44, 95% CI: 0.20, 0.93) (Mirmiran et al., 2019).

Mixed findings have been reported with fruit intake. One study in the USA found no clear association with fruit & fruit juice intake (Chen et al., 2012). In China, a study associated higher fruit intake with lower risk (Zhou et al., 2019), while another study reported higher risk with higher intake (Huang et al., 2017).

Refined cereal products & high sugar products: In Spain, intake of refined cereals less than once per week and cookies and pastries of less than 4 times per week versus more, were associated with a lower risk (Ruiz-Gracia et al., 2016).

Coffee: Moderate coffee drinking (0.5-7 cups per week) was associated with lower risk, RR 0.50; 95% CI 0.29, 0.85 among American and Swedish women (Adeney et al., 2007), while another study in Denmark showed no association (Hinkle et al., 2015).

Table 1.4: Association between nutrients, foods, food groups and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
Saldana et al, 2004 Pregnancy, Infection, and Nutrition Study Cross sectional	1,698 (89) USA	FFQ (validated)	During pregnancy (second trimester)	OGTT C & C*	Fat, carbohydrate, energy	Maternal age, parity, BMI*, history of GDM, ethnicity & total energy intake	Modelling showed that dietary addition of 100 kcal from carbohydrates resulted in a 9% decrease in risk. Substituting calories for fat from carbohydrates showed an increased risk, RR=1.1 (95% CI: 1.02-1.10). Predicted probability of GDM reduced by half with a 10% decrease in dietary fat and 10% increase in carbohydrates.
Zhang et al., 2006a Nurses' Health Study II Prospective	13,110 (758) USA	133-item FFQ (validated)	Pre-pregnancy	From medical records (mainly NDDG)*	Red meat, processed meat, bacon & hot dogs	Maternal age, parity, BMI*, history of GDM, family history of T2DM, ethnicity, lifestyle & total energy intake.	Diet high in red and processed meat was associated with a higher risk. Increment of one daily serving of red and processed meat increased GDM, Red meat - RR: 1.61 (95% CI: 1.25-2.07) & Processed meat - 1.64 (95% CI: 1.13-2.38).
Zhang et al., 2006b Nurses' Health Study II Prospective	13,110 (758) USA	133-item FFQ (validated)	Pre-pregnancy	From medical records (mainly NDDG)*	Total dietary fibre and cereal or fruit fibre	Maternal age, parity, BMI*, history of GDM, family history of T2DM, ethnicity, lifestyle & total energy intake.	Dietary total fibre, cereal and fruit fibre were strongly associated with lower GDM risk. Each 10-g/day increment in total fibre intake was associated with 26% (95% CI: 9-49) reduction in risk; each 5-g/day increment in cereal or fruit fibre was associated with a 23% (95% CI: 9-36) or 26% (95% CI: 5-42) reduction, respectively.
Adeney et al., 2007 The Omega study Prospective	1744 (75) USA & Sweden	Intake of coffee Women's Health Initiative FFQ (validated)	Pre-pregnancy	NDDG*	Coffee intake: Zero-no intake, moderate- ≤7 cups/ week, high ->7 cups per week)	Age, smoking during pregnancy, alcohol use before pregnancy maternal race, pre-pregnancy BMI*, hypertension & average daily caloric intake.	Moderate caffeinated coffee intake significantly reduced risk (RR 0.50; 95% CI 0.29-0.85) compared with no consumption. No risk reduction was associated with decaffeinated coffee intake.

Table 1.4: Association between nutrients, foods, food groups and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
Hinkle et al., 2015 Danish National Birth cohort Prospective	57, 882 (912) Denmark	"How many cups of coffee do you drink daily? (mug=2 cups, 1 pot=8 cups=1 L).	1 st trimester	National Hospital Discharge Register & interviews	Coffee (0; 0.5-3; 4-7; ≥8 cups/day)	Age, SES*, parity, pre-pregnancy BMI*, smoking & cola intake.	No association of coffee with GDM. There was suggestion of a protective, but non-significant association with increasing coffee, ≥8 versus 0 cups/day, RR: 0.89 (95%CI 0.64-1.25).
Radesky et al, 2008 Project VIVA Prospective	1,733 (91) USA	140-item FFQ (validated)	During pregnancy (first trimester)	OGTT C & C*	FA, TFA, SFA, PUFA & MUFA n-3 & n-6.	Maternal age, BMI*, history of GDM, family history of T2DM, ethnicity, lifestyle & total energy intake	Intake of n-3 fatty acids was associated with increased risk, OR: 1.11 (95% CI: 1.02-1.22] per 300 mg/day.
Chen et al, 2009 Nurses' Health Study II Prospective	13,475 (860) USA	133-item FFQ (validated)	Pre-pregnancy	Self-report, confirmed from medical records (mainly NDDG)*	SSB*, colas Other diet beverages	Maternal age, race, parity, smoking, alcohol intake, BMI*, PA* & Western dietary pattern	Compared with women who consumed <1 serving/month, those who consumed ≥5 servings/week of SSB (cola) had a 22% greater risk, RR: 1.22, (95% CI: 1.01-1.47). No association with for other SSBs and diet beverages.
Qiu et al., 2011a Omega and Alpha studies Prospective	3,158 (158) USA	121-item FFQ (validated)	Pre-pregnancy (peri-conception) and first trimester	OGTT C & C*	Eggs Cholesterol	Maternal age, race/ethnicity, BMI*, PA*, energy intake, and intakes of meat, fibre, vitamin C, & SFA*.	Higher egg intake increased GDM risk. High (≥7eggs/wk.) vs. low intakes (<7eggs/wk): Omega: RR 1.77 (95% CI: 1.19-2.63) Alpha: OR 2.65 (95% CI: 1.48-4.72) High vs. low quartiles of cholesterol: Omega: RR 2.35 (95% CI: 1.35-4.09) Alpha: OR 2.94 (95% CI: 1.14-7.60).
Qiu et al, 2011b Omega and Alpha studies Prospective	3158 (158) USA	121-item FFQ (validated)	Pre-pregnancy (peri-conception) and first trimester	OGTT C & C*	Heme iron	Maternal age, education, reproductive and medical histories. height, pre-pregnancy weight, energy intake, smoking, PA*, red and	Heme iron intake was positively associated with GDM risk (p-trend=0.04). After adjusting for confounders, highest heme iron intake levels (≥1.52 vs. <0.48 mg per day) had a 3.3-fold-increased GDM risk (95% CI 1.02-10.72). A 1-mg per day increase in heme iron was associated with a 51% increased GDM risk, RR: 1.51 (95% CI: 0.99-

Table 1.4: Association between nutrients, foods, food groups and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
						processed meat, SFA* & cholesterol.	2.36). Non-heme iron was inversely (not significant), associated with GDM risk.
Bowers et al, 2011 Nurses' Health Study II Prospective	13,475 (867) USA	133-item FFQ (validated)	Pre-pregnancy	From medical records (mainly NDDG)*	Heme iron, dietary total iron & non-heme iron	Maternal age, family history of T2DM, parity, smoking, BMI*, PA*, alcohol intake, glycaemic load, PUFA*, cereal fibre & energy intake.	Dietary heme iron intake was positively associated with GDM risk. RR across increasing quintiles of heme iron were 1.11 (95% CI: 0.87–1.43), 1.31 (95% CI: 1.03–1.68), 1.51 (95% CI: 1.17–1.93), and 1.58 (95% CI: 1.21–2.08), respectively (p-trend 0.0001). Every 0.5-mg daily increase of heme intake was associated with higher risk RR: 1.22 (95% CI: 1.10–1.36). No associations for total dietary, non-heme, or supplemental iron intake.
Chen et al., 2012 Nurses' Health Study II Prospective	13,475 (860) USA	133-item FFQ (validated)	Pre-pregnancy	Medical records (NDDG)*	Fruits & fruit juices	Maternal age, parity, race, smoking, alcohol intake, PA*, family history of T2DM, BMI* & other dietary factors.	High fruit intake not associated with increased GDM. 2 nd & 4 th vs. lowest quintiles showed slightly lower risk. Lowest to highest quintile of whole fruit consumption were 1.00 (reference), 0.80 (95% CI 0.65–0.98), 0.90 (0.73–1.10), 0.80 (0.64–1.00), and 0.93 (0.76–1.16). Association with fruit juices was nonlinear, with lowest risk with modest consumption (3 rd quintile), RRs: 1.00, 0.82 (0.66–1.01), 0.78 (0.63–0.96), 0.84 (0.68–1.04), and 1.00 (0.81–1.23).
Bowers et al, 2012 Nurses' Health Study II Prospective	13,475 (860) USA	133-item FFQ (validated)	Pre-pregnancy	Medical records (NDDG)*	TFA*, AFA*, VFA*, SFA*, TFA*, PUFA*, MUFA*, PUFA/SFA* ratio, Cholesterol, n-3* & n-6*	Maternal age, race, family history of T2DM, parity, smoking, BMI*, PA*, alcohol intake, energy intake, cereal fibre, glycaemic load, cholesterol & TFA*.	Across increasing quintiles of animal fat, RRs (95% CIs) for GDM were 1.00 (reference), 1.55 (1.20–1.98), 1.43 (1.09–1.88), 1.40 (1.04, 1.89), and 1.88 (1.36–2.60) (p-trend = 0.05). Corresponding RRs (95% CIs) for dietary cholesterol were 1.00, 1.08 (0.84, 1.32), 1.02 (0.78–1.29), 1.20 (0.93–1.55), and 1.45 (1.11–1.89) (p-trend = 0.04). Energy from animal fat vs that from carbohydrates increased GDM risk, RR: 1.13 (1.08–1.18), $P < 0.0001$. No associations for other fat- subtypes.

Table 1.4: Association between nutrients, foods, food groups and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
Bao et al., 2013 Nurses' Health Study II Prospective	15,294 (870) USA	FFQ (validated)	Pre-pregnancy	Medical records (NDDG)*	Total protein, animal protein & vegetable protein	Maternal age, race, family history of T2DM, parity, smoking, BMI*, PA*, alcohol intake, energy intake, cholesterol intake, glycaemic load & fibre.	Higher animal protein intake, (red meat), was associated with higher GDM. Higher vegetable protein (nuts), was associated with lower GDM. Comparing the highest with the lowest quintiles, RR: 2.05 (95% CI: 1.55–2.73) for total red meat and 0.73 (95% CI: 0.56–0.95) for nuts, respectively. Substitution of red meat with poultry, fish, nuts, or legumes showed a significantly lower GDM risk.
Bao et al., 2014 Nurses' Health Study II Prospective	15,027 (847) USA	133-item FFQ (validated)	Pre-pregnancy	Self-report, confirmed medical records (NDDG)*	Fried foods	Maternal age, parity, BMI*, history of GDM, family history of T2DM, ethnicity, lifestyle & total energy intake	Consumption of total fried foods 1–3, 4–6 and ≥ 7 times/week, vs. <1 week, had RR (95% CI) 1.13 (0.97, 1.32), 1.31 (1.08–1.59) and 2.18 (1.53–3.09), respectively (p-trend < 0.001). Association persisted after adjustment for BMI (p-trend = 0.01). Higher GDM risk was associated with fried food consumption outside home, not at home.
Dominguez et al., 2014 The SUN project Prospective	3048 (159) Spain	136-item FFQ (validated)	Pre-pregnancy	Two-step NDDG*	Fast food	Maternal age, family history of T2DM, CVD/HTN*, smoking, BMI*, PA*, parity, alcohol intake, energy intake, adherence to Mediterranean	Higher consumption of fast food was positively associated with GDM, OR: 1.31 (95% CI: 0.81–2.13) and 1.86 (95% CI: 1.13–3.06) for the intermediate and high categories, respectively, versus the lowest category of baseline fast food consumption (p-trend: 0.007).

Table 1.4: Association between nutrients, foods, food groups and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
						pattern**, fibre & SSB* intake.	
Bao et al. 2016 Nurses' Health Study II Prospective	15,632 (854) USA	FFQ (validated)	Pre-pregnancy	Self-report, confirmed medical records (NDDG)*	Potato	Maternal age, race/ethnicity, family history of T2DM*, parity, smoking, BMI*, PA*, energy intake & aHEI**.	Potato intake was positively associated with GDM. Replacing 2 weekly servings of potatoes with other vegetables, legumes, and whole grain foods was associated with a 9-12% lower risk. The adjusted relative risks for GDM for total potato consumption of 1, 2-4, and ≥5 servings/week, compared with <1 serving/week, were 1.18 (95% confidence interval 0.95-1.45), 1.21 (0.99-1.48), and 1.40 (1.08-1.83), respectively (p-trend=0.03 trend).
Mohanty et al. 2016 The Omega study Prospective	3279 (160) USA	Seafood Intake Scale FFQ (validated)	3 months pre-pregnancy and 1st trimester.	Two-step, C & C* at gestational week 24-28	Total seafood shellfish lean fish fatty fish, EPA* & DHA*.	Maternal age, race, education, marital status, pre-pregnancy BMI*, energy intake, PA*, smoking, alcohol intake, parity, red & processed meat intake BMI*, age & parity	No association with GDM.
Ruiz-Gracia et al., 2016 The St. Carlos Study Retrospective	1750 (185) Spain	Qualitative FFQ Of food groups	Early pregnancy	75-g, 2-h OGTT IADPSG*	4 nutritional patterns: high consumption of juices and sweet drinks, pastries and cookies, and high glucose-load refined cereals like rice, pasta		GDM ORs (95%CI) for intake/week were: Nuts >3 times: 0.59 (0.39-0.91; p < 0.015), refined cereals ≤1 serving: 0.72 (0.58-0.89; p < 0.003), Juices <4 servings: 0.77 (0.62-0.95; p < 0.017), Cookies and pastries <4 servings: 0.71(0.57-0.89; p < 0.003) as compared to opposite of intakes mentioned above.

Table 1.4: Association between nutrients, foods, food groups and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
					and white breads, and a low consumption of nuts.		
Lamyian et al., 2017 Prospective	1026 (71) Iran	168-item FFQ (validated)	During pregnancy	100-g, 3-hr OGTT ADA* 2016	Total fast food intake (hamburgers, sausages, bologna (beef), pizza and French fries).	BMI*, PA*, history of GDM, family history of T2DM, GWG*, age, education, total energy intake, total fibre and cholesterol intake	GDM risk for high total fast food consumption was (OR: 2.12, 95% CI: 1.12–5.43) (lowest quartile: <42.6 g/ week vs. highest quartile: >175 g/ week) and for french fries (OR: 2.18, 95% CI: 1.05–4.70). No association for hamburgers, sausages, bologna (beef), pizza and GDM.
Huang et al., 2017 Prospective	772 (169) China	3-day diary	Mid-pregnancy	75-g, 2-hr OGTT IADPSG	Fruit	Age, SES*, pre-pregnancy BMI*, GWG, family history of T2DM, smoking & alcohol use.	Greater total fruit consumption was associated with higher risk (highest vs. lowest quartile, OR: 4.82, 95% CI 2.38 to 9.76).
Pang et al., 2017 GUSTO Prospective	980 (175) Malay, Chinese & Indian Singapore	3-day diary, 24-hour recall	26-28 weeks	75-g, 2-hr OGTT WHO, 1999	Total dietary, animal & vegetable protein	Age, parity, BMI, T2DM family history, smoking, alcohol & energy	Higher total dietary, animal (*seafood & dairy) & vegetable protein was associated with a higher GDM risk. Total: 2.15 (95% CI 1.27-3.62 Animal: OR 2.87; 95% CI 1.58-5.20 Vegetable: OR 1.78; 95% CI 0.99-3.20 p-trend for all (<0.01)
Goshtasebi et al., 2018 Prospective	1026 (71) Tehran, Iran	168-item FFQ (validated)	First half of pregnancy	ADA* 2016	Legumes and starchy vegetables, including (potatoes, corn, squash, green pea & green lima beans)	BMI*, history of GDM, family history of T2DM*, age, education, total energy intake, total fibre & cholesterol intake.	Higher vegetable consumption was negatively associated with GDM risk; OR for ≥ 2.1 servings/week compared to less, was 0.53 (95% CI: 0.29–0.97). An association which disappeared after adjustment for confounding factors. For legumes, higher consumption was negatively associated with GDM; OR for those who consumed ≥ 3.3 servings/week compared to less was 0.38

Table 1.4: Association between nutrients, foods, food groups and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
							(95% CI: 0.19–0.74), after adjustment for confounding factors. No association with the total starchy or other starchy vegetables and GDM.
Liang et al., 2018 Prospective	6299	128-item FFQ (validated)	1 year before pregnancy, 1st & 2 nd trimesters	75-g, 2-hr, OGTT IADPSG	Total dietary, animal & vegetable protein	Age, pregravid BMI*, , parity, PA*, family history of T2DM, PCOS, energy & macronutrient intake & SES*	Mid-pregnancy higher intake of total & animal protein was associated with higher GDM risk. Higher meat consumption & dairy intake was associated with higher GDM risk. Total-protein: RR: 1.92 (95% CI: 1.10, 3.14), p-trend =0.04 Animal protein: RR: 1.67 (95% CI: 1.19, 2.93), p-trend =0.03
Mari-Sanchis et al., 2018 Prospective	3298 (172) Spain	136-item FFQ (validated)	Pre-pregnancy	100-g OGTT NDDG*, C&C*	Total meat was defined as all types of meat	BMI*, family history of T2DM, parity, , smoking, PA* & HTN*	Total meat consumption was significantly associated with a higher risk of GDM (OR = 1.67, 95% CI 1.06–2.63, p-trend 0.010) for the highest versus the lowest quartile of consumption. Associations strong for red & processed meat.
Mirmiran et al., 2019 Prospective	1026 (71) Tehran, Iran	168-item FFQ (validated)	Early pregnancy (≤6 weeks gestation)	ADA* 2016	Fruit, vegetable & dairy	BMI*, history of GDM, family history of T2DM, age, level of education, total energy intake, total fibre & cholesterol intake.	High fruit and vegetable intakes were negatively associated with GDM risk. Compared with women who consumed < 2.1 servings/day, OR for those who consumed ≥ 4.9 servings/day was 0.44 (95% CI: 0.20–0.93). No association with dairy.
Zhou et al., 2019 Prospective	3300 (378) China	200-item FFQ (validated)	Mid-pregnancy (24 weeks gestation)	IADPSG	Fruit	Age, PA*, ethnology, pre-pregnancy BMI*, GWG*, education, income, smoking, parity, T2DM family history, energy & other food groups.	Fresh fruit intake was associated with lower risk. Comparing lowest to highest quintiles, OR (95% CI) were 0.80 (0.56, 1.12), 0.74 (0.52, 1.05), 0.63 (0.44, 0.92), and 0.41 (0.27, 0.62), p-trend < 0.001.

Table 1.4: Association between nutrients, foods, food groups and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
*Abbreviations: NDDG-National Diabetes Data Group; C & C - Carpenter & Coustan; IADPSG - International Association of Diabetes and Pregnancy Study Groups; ADA - American Diabetes Association; BMI - body mass index; PA - physical activity; GWG - gestational weight gain; SES - Socio Economic Status; CVD - Cardiovascular Disease; HTN - Hypertension; MED score - Mediterranean Diet score; SSB - Sugar Sweetened Beverage, aHEI - Alternate Healthy Eating Index, FA - total fatty acid; AFA - animal FA; VFA - vegetable FA; SFA- Saturated FA; TFA - Trans FA; PUFA - Polyunsaturated FA, MUFA - Monounsaturated FA; n-3 - Omega-3 FA; n-6 - Omega-6 FA; EPA: eicosapentaenoic acid; DHA - docosahexaenoic acid. **Terminology: Med Score, aHEI are diet indices and refer to patterns high in fruit, vegetables, nuts, legumes, soy, fish, seafood, whole grains and low intake of red and processed meats. aHEI also includes moderate alcohol, in addition to multivitamin use, higher ratio of polyunsaturated fatty acid to saturated fatty acid (PUFA: SFA) and lower intakes of transfat. DASH assesses high intakes of low-fat dairy, lower sweetened beverages and sodium. *** Statistical abbreviations: RR: Relative Risk; OR: Odds Ratio & 95% CI: 95% Confidence Interval.							

1.5.4. Association between diet patterns and GDM risk

A literature search investigating dietary patterns and GDM risk identified 18 studies (systematic literature search strategy in Appendix A, page 285). Table 1.5, pages 28 - 34) presents the characteristics and findings of these studies. They were carried out in a range of countries (including the USA, Brazil, Australia, Spain & other Mediterranean countries, Iceland, China, Iran and Singapore). There was not a single study in India. Studies were heterogeneous in terms of time periods, study design, sample size, FFQ or dietary assessment tools, definition and number of the food groups, timing of assessment of diet before or during pregnancy, diagnostic criteria and prevalence of GDM and confounders adjusted for. Due to the diversity in food culture and preferences, availability and affordability of foods, different diet patterns were derived in different populations. Dietary pattern studies in developed countries (USA, Iceland and Australia) derived clear healthy and unhealthy diet patterns, whereas studies in developing countries (China and Brazil) derived patterns that were not clearly healthy or unhealthy. A reason for these differences could be lower awareness of healthy and unhealthy foods (Green et al., 2016).

Definitions of healthy diet patterns varied between studies and included the Prudent, traditional, Mediterranean, seafood-noodle based pattern, vegetarian or plant-based diet patterns, diet patterns adhering to recommendations such as Dietary Approach to Stop Hypertension (DASH) and Alternate Healthy Index (aHEI) (details in table 1.5). Definitions of unhealthy patterns also varied, and were described as Western, meat-based, meats, sweets & snacks and sweets & seafood. The components of these patterns are shown in detail in table 1.5. Healthy diet patterns were associated with a lower GDM risk in eleven studies (Zhang et al., 2006a; Tobias et al., 2012; Karamanos et al., 2014; Schoenaker et al., 2015; He et al., 2015; Tryggvadottir et al., 2016; De-Seymour et al., 2016; Izadi et al., 2016; Chen et al., 2019; Asadi et al., 2019 & Zamani et al., 2019). The varying definitions of healthy patterns limit specific conclusions. For instance, refined grains were characteristic of a prudent pattern in China (Chen et al., 2019), while in the USA they were included in the unhealthy western pattern (Zhang et al., 2006a). Red meat was included in a prudent healthy pattern in Iran (Asadi et al., 2019), but by others as part

of unhealthy diet patterns (Zhang et al., 2006a & Tobias et al., 2012).

Common characteristics of healthy patterns were higher consumption of whole-grain foods, legumes, fruits, vegetables, greens, dairy, nuts, seeds, fish, poultry and egg; and lower intake of refined grains, red & processed meat, fried food such as fries & fast food such as pizza and burgers, sweets, desserts & SSB. Healthy dietary patterns may reduce GDM risk due to a lower dietary energy density and glycaemic load as well as higher content of antioxidants, polyphenols, fibre and micronutrients such as vitamin C and magnesium from increased intake of fruits and vegetables (Chen et al., 2019). Healthy diet patterns may also have a beneficial effect on adiposity, which reduces GDM risk (Chen et al., 2019).

Unhealthy diet patterns were associated with a higher risk in five out of 18 studies (Schoenaker et al., 2015; Zhang et al., 2006a; He et al., 2015; Sedaghat et al., 2017 & Du et al., 2017). Three studies found no association between dietary patterns and GDM risk (Radesky et al., 2008; Nascimento et al., 2016 & Mak et al., 2018).

In 7 studies, diet exposure was assessed before pregnancy and 12 studies assessed diet during pregnancy. A study in China which assessed diet patterns at 3 time-points (1-year pre-pregnancy, 1st and 2nd trimester) found similar dietary patterns across all the time points with no differences in their association with GDM (Chen et al., 2019). Similar findings have been reported in Spain and the UK suggesting diet patterns may remain stable before and during pregnancy (Cuco et al., 2006 & Crozier et al., 2009). While dietary pattern studies during pregnancy are important, it is more important to study diet patterns during the peri-conceptual period to actually prevent GDM. This is because, although GDM is detected in late pregnancy, the source of metabolic dysfunction is established much before (Catalano et al., 2014) probably during the peri-conceptual period. This period for women is defined as 6 months around conception that includes oocyte growth (14 weeks before conception), fertilization and embryogenesis (10 weeks after conception) (Steegers-Theunissen et al., 2013) (table 1.5).

The quality of these observational studies (tables 1.4 & 1.5) exploring the association between food groups/diet patterns and GDM is generally good. Strengths include prospective study designs with temporality (exposure preceding outcome). Diet was assessed using validated FFQs. Most studies

adjusted for confounders including age, gravidity, medical history, family history of GDM and T2DM, PCOS and ethnicity. Some studies adjusted for physical activity and sedentary behaviour, another important modifiable factor related to GDM risk. To account for the limitation of assessing single nutrients/foods, some studies adjusted for multiple dietary factors apart from the dietary constituent under study. Limitations were that few studies adjusted for SES as a confounding factor. The majority of the evidence for diet-GDM associations came from the Nurse's Health Study, followed by the Omega, Alpha studies and the Danish birth cohort, which had large sample sizes. Studies used varying OGTT diagnostic criteria such as Carpenter and Coustan, NDDG, ADA, WHO 1999 and IADPSG, and some studies included self-reported GDM results confirmed by national health records. While these observational studies form the basis for thinking that diet may have a role in preventing GDM, they need to be interpreted with caution, because of the potential for residual confounding. For instance, egg was associated with an increased GDM risk in the Alpha study, but egg eaters were also more likely to smoke, have a higher BMI and have an overall low quality diet assessed by aHEI recommendations, which could have contributed to higher GDM risk (Mijatovic-Vukas et al., 2018). Although the Alpha study adjusted for smoking, BMI and other dietary factors including energy, fibre, vitamin C, saturated fat, meat and vitamin C, residual confounding cannot be ruled out completely.

Table 1.5: Association between dietary patterns and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
Zhang et al., 2006a Nurses' Health Study II Prospective	13,110 (758) USA	133-item FFQ	Pre-pregnancy	Medical records (NDDG*)	Prudent pattern (high intake of fruit, green leafy vegetables, poultry and fish). Western pattern (high intake of red meat, processed meat, refined grain products, sweets, French fries and pizza).	Maternal age, parity, BMI*, history of GDM, family history of T2DM, ethnicity, lifestyle, total energy intake.	Highest vs. lowest quintile: Western pattern scores, RR: 1.63, 95% CI: 1.20-2.21, p-trend=0.001. Prudent pattern scores, RR: 1.39, 95% CI: 1.08-1.80, p-trend=0.01.
Radesky et al., 2008 Project Viva Prospective	1,733 (91) USA	140-item FFQ	During pregnancy (first trimester)	Medical records (NDDG*)	Prudent pattern (high in vegetables, fruit, legumes, fish, poultry, eggs, salad dressing and whole grains). Western pattern (red and processed meats, SSB, French fries, high-fat dairy products, desserts, butter and refined grains).	Maternal age, pre-pregnancy, BMI*, race/ethnicity, previous gestational diabetes, history of T2DM in participant's mother and smoking during pregnancy.	No association with GDM
Tobias et al., 2012 The Nurses' Health Study II Prospective	15254 (872) USA	61-item FFQ (validated)	Pre-pregnancy	Glucose screening (83%) NDDG*	Alternate Mediterranean Diet (aMED), Dietary Approach to stop Hypertension (DASH), and alternate Healthy Eating Index (aHEI). All 3 patterns high on fruit, vegetables, nuts, legumes, soy, fish, seafood, whole grains and low intake of red and processed meats. aHEI also includes moderate alcohol, in addition to multivitamin use, higher ratio of polyunsaturated fatty acid to saturated fatty acid (PUFA: SFA) and lower intakes of transfat. DASH assesses high intakes of low-fat dairy, lower SSB and sodium.	BMI*, PA*, sedentary time at home, gravidity, smoking status, parental history of T2DM & race or ethnicity.	Healthy dietary patterns including the aMED, DASH, and aHEI were significantly associated with a lower risk of GDM aMED: RR 0.76, 95% CI: 0.60-0.95 DASH: RR: 0.66, 95% CI 0.53-0.82 aHEI: RR 0.54, 95% CI: 0.43-0.68).

Table 1.5: Association between dietary patterns and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
Karamanos et al., 2014 Prospective	1076 (102: ADA, 312: IADPSG) 10 Mediterranean countries, namely Algeria, France, Greece, Italy, Lebanon, Malta, Morocco, Serbia, Syria and Tunisia	78 questions dietary questionnaire Mediterranean Diet Index	During pregnancy	ADA* 2010, IADPSG* 2012	Mediterranean Diet Index (MDI) (based on frequency of intake of bread, cereals, legumes, vegetables, fruits, meat, fish, eggs, the ratio of olive oil to animal fat, potatoes, cheese and dairy products).	Age, BMI*, T2DM history in the family, weight gain & energy intake.	Better adherence to the MDI* (higher tertile of MDI* distribution), 8.0% vs 12.3%, OR: 0.62, p=0.030 by ADA and 24.3% vs 32.8%, OR=0.66, p=0.004 by IADPSG* 2012 .
Schoenaker et al., 2015 The Australian Longitudinal Study on Women's Health Prospective	3853 (292) Australia	101-item FFQ (validated)	Pre-pregnancy	Two-step: 1-h 50-g GCT, and confirmatory 75-g OGTT fasting PG ≥ 5.6 mmol/l and/or 2-h PG ≥ 8.0 mmol/l	Meats, snacks and sweets pattern (red and processed meat, cakes, sweet biscuits, fruit juice, chocolate and pizza). Fruit and low-fat dairy (high consumption of fruits and low-fat dairy including yoghurt, low-fat cheese, and skimmed milk) Mediterranean-style pattern (vegetables, legumes, nuts, tofu, rice, pasta, rye bread, red wine and fish). Fruit and low-fat dairy pattern (fruits and low-fat dairy including yoghurt, low-fat cheese and skimmed milk). Cooked vegetables pattern (carrots, peas, cooked potatoes, cauliflower and pumpkin).	Maternal age, education, energy intake, parity, hypertensive disorder of pregnancy, PCOS, inter-pregnancy interval, smoking, BMI* & PA*.	Fruit and low-fat dairy and Cooked vegetables patterns: no association. 'Meats, snacks and sweets' pattern was associated with higher GDM risk (RR:1.38, 95% CI: 1.02-1.86). Adjustment for BMI attenuated the results (RR:1.35, 95% CI: 0.98-1.81). 'Mediterranean-style' pattern was associated with lower GDM risk in the fully adjusted model (RR: 0.85, 95% CI: 0.76-0.98).

Table 1.5: Association between dietary patterns and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
He et al., 2015 Prospective	3063 (544) Guangzhou (Southern China)	FFQ (validated)	During pregnancy (2 nd & 3 rd trimester)	WHO* 2013	Vegetable (root vegetables, beans, mushrooms, melon vegetables, seaweed, other legumes, fruits, leafy and cruciferous vegetables, processed vegetables, nuts, and cooking oil), Protein-rich (poultry, red meat, animal organ meat, grains (mainly refined), processed meat, fish, soups, leafy and cruciferous vegetables and eggs). Prudent (dairy products, nuts, eggs, fish, soups, fruits, and infrequent intake of processed meat, SSB, and processed vegetables). Sweets and seafood (Cantonese desserts, molluscs and shellfish, SSB and low intakes of grains (mainly refined) and leafy and cruciferous vegetables).	Maternal age, education, income, family history of T2DM, parity, BMI* & other dietary patterns.	Highest tertile of the vegetable pattern was associated with a decreased risk of GDM (relative risk (RR) 0.79, 95 % CI 0.64, 0.97), compared with the lowest tertile, whereas the highest tertile of the sweets and seafood pattern was associated with an increased risk of GDM (RR 1.23, 95 % CI 1.02, 1.49). No significant association was found for other patterns. Pattern. The protective effect of a high vegetable pattern score was more evident among women who had a family history of diabetes (p for interaction: 0.022).
Tryggvadottir et al., 2016 Prospective	168 (33) Iceland	4-day weighted diet records	During pregnancy (second trimester)	WHO* 2013	Prudent pattern (seafood; eggs, vegetables, fruits and berries, vegetable oils, nuts and seeds, pasta, breakfast cereals, coffee, tea and cocoa powder, and negative factor loadings for soft drinks and French fries).	Maternal age, parity, pre-pregnancy weight, weekly GWG, total MET & energy intake.	Adherence to prudent dietary pattern was associated with lower risk of GDM. OR: 0.36, 95% CI: 0.14-0.94.
De Seymour et al., 2016 GUSTO	909 (160) Singapore	24-h recall	During pregnancy (second trimester)	WHO* 1999	Vegetable-fruit-rice-based pattern Seafood-noodle-based pattern	Maternal age, ethnicity, education, income, E intake, family history of diabetes, GDM history,	Adherence to seafood-noodle-based-diet was associated with a lower

Table 1.5: Association between dietary patterns and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
Prospective					Pasta-cheese-processed meat pattern	smoking, BMI, birth order, & alcohol intake	likelihood of GDM (OR: 0.74, 95% CI:0.59, 0.93).
Izadi et al., 2016 Case-control	460 (200) Iran	3 24-hr recalls	During pregnancy	Fasting glucose >95 mg/dL or 1-h postprandial glucose >140 mg/dL	DASH & MED scores	Age, energy, parity & SES*	Participants in the highest tertile of the MED diet had 80% lower risk for GDM compared with those in the lowest tertile (OR, 0.20; 95% CI, 0.50–0.70, p-trend= 0.006). Greater adherence to the DASH eating plan was associated with 71% reduced risk for GDM (OR, 0.29; 95% CI, 0.17–0.48, p-trend = 0.006).
Nascimento et al., 2016 Prospective	841 (95) Brazil	81-item FFQ (validated)	Early – mid pregnancy (15-20 weeks)	75-g, 2 h OGTT IADPSG*	Traditional pattern (dairy products, fruits, vegetable and fish). Mixed pattern (fried food, pizza, juice, manioc flour, red meat and candies). Western pattern (eggs, white bread, cookies, pasta, pizza, fried food, chicken, candies, chocolate, salty snacks and SSB).	Age, maternal education, pre-pregnancy BMI & parity	No differences among GDM incidence according to these three dietary patterns.
Sedhaghat et al., 2017 Case-control	388 (122) Iran	FFQ	One year before pregnancy	100-g, 3-hour OGTT	Western pattern (high in sweets, jams, mayonnaise, SSB, salty snacks, solid fat, high-fat dairy products, potatoes, organ meat, eggs, red meat, processed foods, tea, and coffee). Prudent dietary pattern (liquid oils, legumes, nuts and seeds, fruits and dried fruits, fish and poultry whole, and refined grains).	Pre-pregnancy weight, gestational age, PA*, family history of T2DM, housing ownership & building area.	Western dietary pattern was associated with increased risk of gestational diabetes mellitus before and after adjustment for confounders (OR: 1.97, 95% CI: 1.27–3.04, OR = 1.68, 95% CI: 1.04–2.27). No association for prudent pattern.

Table 1.5: Association between dietary patterns and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
Du et al., 2017 Prospective	753 (64) Northern China	2 24-hr recalls	Late pregnancy (3 days before GDM diagnosis)	Serum glycosylated hemoglobin (HbA1c)*	Four dietary patterns were identified: Western pattern (dairy, baked/fried food and white meat). Traditional pattern (light-colored vegetables, refined grain, red meat and tubers). Mixed pattern (edible fungi, shrimp/shellfish and red meat) and Prudent pattern (dark-coloured vegetables and deep-sea fish).	Age, pre-pregnancy BMI*, education, smoking, family history of T2DM, parity, daily food energy intake & PA*.	Compared with the prudent pattern, both the Western pattern and the traditional pattern were associated with an increased risk of GDM (OR = 4.40, 95% CI: 1.58-12.22; OR = 4.88, 95% CI: 1.79-13.32) and a high level of HbA1c (OR = 12.37, 95% CI: 1.47-103.91; OR = 26.23, 95% CI: 2.54-270.74). Compared to the lowest quartile (Q), Q3 of the Western pattern scores and Q3-Q4 of the traditional pattern scores were associated with a higher GDM risk.
Donazar-Ezcurra et al., 2017 Prospective	3455 (173) Spain	136-item FFQ	Pre-pregnancy	GDM reported by participants & defined a score based on risk age, BMI and unhealthy Diet pattern.	Western pattern (meat-based products and processed foods). Mediterranean pattern (high consumption of vegetables, fruits, fish and non-processed foods).	Age, BMI*, family history of T2DM, smoking status, PA* & gravidity.	Highest quartile of adherence to Western pattern was associated with higher GDM compared with the lowest quartile (OR: 1.56; 95% CI: 1.00-2.43). No association for adherence to the Mediterranean diet pattern. Women who adhered to a low-risk lifestyle before pregnancy (maintaining a healthy body weight, getting pregnant before 28

Table 1.5: Association between dietary patterns and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
Mak et al., 2018 Prospective	1337 (199) Western China	109-item FFQ (validated)	Early –mid pregnancy (15-20 weeks)	75-g, 2-h OGTT IADPSG*	3 dietary patterns were identified: Plant-based pattern Meat-based pattern High protein-low starch pattern.	Gravidity & T2DM family history.	years and avoiding a Western pattern had a 76 % lower risk of GDM (OR:0.24; 95 % CI: 0.10-0.55). No association between dietary patterns and GDM risk. A significant reduction in GDM risk among overweight women (BMI≥24 kg/m ²), OR: 0.94, when comparing the highest versus the lowest score of the high protein-low starch pattern.
Sartorelli et al., 2019 Prospective	785 (139) Brazil	2 24-hr recalls	Late pregnancy (24-39 weeks)	75-g, 2 h OGTT WHO* 2013	Pattern 1 (high rice, beans, and vegetables, with low full-fat dairy products, biscuits, and sweets). Pattern 2 (high red meats, full-fat dairy products, chocolate powder and fruits, with low chicken and margarine).	Age, education, smoking status, PA*, parity, prior GDM, and family history of T2DM, excess body weight, total energy intake & dietary underreporting.	Dietary pattern 1 correlated positively with fibre density and negatively with TI* and was inversely associated with GDM (OR: 0.58, 0.36–0.95; p=0.03). Dietary pattern 2 correlated positively with both TI* and fibre density, with no association with GDM found (OR, 1.48; 95% CI, 0.91–2.40; p=0.11).
Chen et al., 2019 Case-control	1464 GDM cases and 8092 non-GDM controls Taiyuan	33-item FFQ	1 year before pregnancy, the first trimester, and the	WHO* 2013	A vitamin-nutrient pattern (rich in carotene, vitamins A, B2, B6, C, folate, calcium, potassium & fibre) across the time periods.	Total energy intake, maternal age, high blood pressure, education, maternal BMI*, parity, and family history of T2DM &	For every quartile increase in the vitamin-nutrient pattern score during one year prior to conception, the first trimester, and the second trimester of

Table 1.5: Association between dietary patterns and GDM risk

Study reference, Study name, Study design	Sample size (N cases) Country	Dietary assessment method	Timing of diet assessment	GDM diagnosis criteria & timing	Diet factors analysed	Confounders Included in analysis	Main Result RR, OR (95% CI)***
	(Northern China)		second trimester of pregnancy			other factors identified by the factor analysis.	pregnancy, the GDM risk decreased by 9% (OR: 0.91, 95% CI: 0.86-0.96), 9% (OR: 0.91, 95%CI: 0.86-0.96), and 10% (OR: 0.90, 95% CI: 0.85-0.95), respectively. Stronger effect was found in women whose age ≤ 30 , primiparous and BMI ≤ 24 with similar effect size across the 3 time periods.
Asadi et al., 2019 Case-control	278 148 GDM cases & 148 control Iran, multi-centre	67-item FFQ (validated)	Recall of diet 1 year before pregnancy, collected during pregnancy.	75-g, 2-hr OGTT ADA*	Western dietary pattern (SSB, refined grain products, fast foods, salty snacks, sweets and biscuit, mayonnaise and saturated oils). Prudent dietary pattern (fruits, low-fat dairy, potato, egg, fish, poultry, nuts, organs meat and red meat).	BMI*, age, family history of T2DM & history of foetal macrosomia.	Prudent pattern was negatively associated with GDM risk (OR: 0.88, 95% CI: 0.44-0.99). No association between adherence to Western pattern and risk of GDM.
Zamani et al., 2019 Case-control	200 GDM cases & 260 non-GDM controls Iran	3 24-hr recalls	During pregnancy	Not-defined	Adherence to the plant-based dietary patterns was scored using three indices of the overall plant-based dietary index (PDI), healthy plant-based diet (hPDI) and unhealthy plant-based diet index (uPDI).	BMI*, age & family history of T2DM	PDI score was inversely associated with risk of GDM (OR: 0.47; 95% CI: 0.28-0.78, $p = 0.004$). No significant association between hPDI (OR: 1.03; 95% CI: 0.64-1.65, $p = 0.884$) or uPDI (OR: 1.65; 95% CI: 0.98-2.78, $p = 0.06$) and GDM risk.

* Abbreviations: NDDG-National Diabetes Data Group; IADPSG - International Association of Diabetes and Pregnancy Study Groups; ADA - American Diabetes Association; HbA1c- Glycated Haemoglobin, WHO - World Health Organisation; BMI - body mass index; PA - physical activity; GWG - gestational weight gain; SES - Socioeconomic Status; MED score - Mediterranean Diet score; Mediterranean Diet Index - MDI; SSB - Sugar Sweetened Beverage, aHEI - Alternate Healthy Eating Index; TI - Thrombogenicity Index.

** Terminology: TI is a ratio between subclasses of SFA (myristic, palmitic, and stearic acids), with a recognized negative action on insulin sensitivity and pancreatic β -cell function and unsaturated fatty acids that improve insulin-stimulated cellular glucose uptake and insulin sensitivity.

*** Statistical abbreviations: RR: Relative Risk; OR: Odds Ratio & 95% CI: 95% Confidence Interval.

1.5.5. Diet interventions and GDM risk

Several intervention studies have investigated the effect of dietary interventions on GDM risk.

SARAS, a pre-conception intervention among Mumbai's slum-dwelling women (n=6513) included a micronutrient-rich snack of green leafy vegetables, fruit, and milk in the intervention group and low micronutrient vegetables (onion and potato) for controls. This study found that out of 1008 women who had an OGTT, GDM prevalence was reduced by almost 50% in the intervention group (7.3%) versus the control group (12.4%) (OR: 0.56, 95% CI: 0.36-0.86, $p=0.008$), after adjusting for pre-pregnancy adiposity and gestational weight gain (GWG). Limitations were that even though all women were offered an OGTT, only half of them agreed, which is unlikely to be a random choice. The overall compliance with supplementation was poor (~50%) by conventional standards. Also physical activity was not measured to explore the exact mechanism for GDM reduction (Sahariah et al., 2016).

The St. Carlos GDM prevention trial among 1000 Spanish normal weight women consisted of an intervention started in early pregnancy, in which advocating a Mediterranean diet and daily supplementation with 40 ml extra virgin oil and 30 grams of pistachios reduced GDM incidence at 6 months (RR = 0.73, 95% CI 0.56, 0.95), compared with the control group with standard diet and limited fat intake (Assaf-Balut et al., 2017).

Most other intervention studies have been done in high income countries among overweight women at risk for GDM. These have focussed on controlling food and caloric intake, and GWG. They have studied variable components of general and individualised dietary, exercise and behaviour change interventions. Dietary intervention components included counselling, ranging from one to many sessions (through dietitians, social media and telephone calls), revolving around healthy eating, and reducing calories, glycaemic index and saturated fats. Activity interventions included exercise advice ranging from three times a week to daily. There was insufficient information on the specificity of dietary elements of the intervention, for instance, the extent of calorie/carbohydrate/fat restriction achieved. If they focussed on improving overall diet quality, it was not always clear whether

this included increasing healthy foods such as wholegrains, fruit and vegetable consumption or reductions in unhealthy components, or both.

In the UPBEAT trial in the UK, obese pregnant women (n=1555) in early pregnancy (15 – 18 weeks) were randomised to either standard antenatal care or 8 weekly diet and activity sessions. Dietary advice was to reduce glycaemic index and load and saturated fat intake, while the exercise intervention emphasised walking at a moderate intensity. Limitations were that the intervention was for just 4 months, compliance was low as 46% women attended less than 4 out of 8 lifestyle education sessions, and about 80% were followed up for glucose tolerance. The authors concluded that the intervention reduced GWG but had no effect on GDM or the incidence of large-for-gestational age (LGA) babies (Poston et al., 2015). Studies with similar interventions have seen no effect on GDM. LIMIT, an Australian RCT, in 2212 overweight and obese pregnant women, with 3-4 face-to-face and online lifestyle sessions with dietary advice that included a balanced diet of carbohydrates, fat, and protein, to reduce intake of foods high in refined carbohydrates and saturated fats, two fruit servings, five vegetable servings, and three dairy servings. Limitations included poor compliance and participants were women from higher SES affecting external validity. Physical activity advice encouraged women to increase walking and being active throughout the day (Dodd et al., 2014). Other Danish intervention studies (LiP and TOP) in >300 obese women showed a reduction in GWG, although showed no impact on the GDM prevalence. The LiP (Lifestyle in Pregnancy) focussed on 4 dietary sessions at 15, 20, 28 and 35 weeks' gestation with an aim to limit GWG to 5 kgs based on Danish dietary recommendations, and have free fitness memberships of 6 months with personal coaching. Both studies pointed that, to see an actual effect for GDM reduction pre-pregnancy interventions may be more beneficial (Vinter et al., 2011). The Treatment for Obese Pregnant (TOP) women included a hypocaloric Mediterranean-style diet advice every 2 weeks and encouraged 11,000 steps daily (Renault et al., 2014).

A Cochrane review that investigated dietary advice interventions in pregnancy and GDM prevention concluded that there is a reduced risk of GDM among women getting dietary advice, compared to standard care, but the evidence was of poor quality and heterogenous (RR: 0.60, 95% CI: 0.35-

1.04) (Tieu et al., 2017). Another Cochrane review covering 23 diet and activity interventions concluded that there is moderate quality evidence that diet and exercise interventions may prevent GDM (RR: 0.85, 95% CI: 0.71, 1.01) and reduce GWG (Shepherd et al., 2017). Another review concluded that diet control involving reduced food intake and moderate exercise versus standard care was effective in reducing GDM (Facchinetti et al., 2014). Another meta-analysis indicated that diet interventions reduced GDM risk in overweight and obese women (RR 0.40, 95% CI 0.18, 0.86) (Rogozińska et al., 2015).

Most individual studies have not found a significant effect, although systematic reviews and metaanalyses combining results of many studies have found a significant effect. Possible reasons for individual intervention studies to have not detected a significant effect on GDM could be because lifestyle behavioural changes take time to see an effect. Other reasons include: differences in health characteristics between intervention and control group, non-generalisability of the sample (e.g. selective sampling), poor compliance and insufficient duration of intervention to detect an effect. Also, women may adopt healthy lifestyle changes even if allocated to a control group. Besides, even motivated participants may find adherence to lifestyle programmes challenging as motivation may drop through the pregnancy. Lifestyle trials starting from pre-pregnancy may be most beneficial, however undertaking such trials are challenging, given that only 50% of pregnancies are planned and many do not attend antenatal clinics until after the first trimester (Egan et al., 2018).

Most of the evidence on intervention studies comes from Western populations, and this limits applicability to LMICs. Compared to Western settings, LMICs have a higher GDM prevalence (25% vs <5%) (Retnakaran et al., 2006), and a double burden of underweight and overweight (Seshiah et al., 2008). In India, there has been a rapid economic and nutrition transition in the last 20 years, in which traditional diets are being replaced by more processed foods (Forouhi et al., 2018). An important focus of most western diet intervention studies to prevent GDM has been restriction of calories and saturated fat to reduce GWG and macrosomia (Shepherd et al., 2017). Some Cochrane reviews have also reported that diet and exercise interventions versus standard care reduced birth weight by 0.89 kg in addition to reducing

GWG and GDM risk (Shepherd et al., 2017). These strategies may be less applicable to Indian settings, where paradoxically GDM occurs in underweight as well as overweight women, and low birth weights are more common and macrosomia less common, suggesting the complexity of the GDM-macrosomia relationship in South-Asian ethnic populations (Tsai et al, 2013). Reducing GDM by reducing intake and GWG may be problematic, because according to the Developmental Origins of Health and Disease (DoHAD) concept, low birth weight may increase T2DM risk (Harder et al., 2007), and similarly GDM risk. Interventional evidence relevant to India comes from the SARAS pre-conception intervention trial, where the authors suggested that a focus on micronutrient-rich foods that are culturally acceptable such as milk, fruits and green leafy vegetables may be an important strategy for GDM prevention in LMIC settings (Sahariah et al., 2016).

1.5.6. Diet & T2DM

Observational evidence: A systematic review and meta-analysis of prospective studies reviewing evidence on food group intake and T2DM risk found that, a higher intake of wholegrains (RR: 0.77; 95% CI 0.71–0.84), fruits (RR: 0.96; 95% CI 0.93–1.00) and dairy (RR: 0.91; 95% CI 0.85–0.97) was associated with a lower risk, while a higher intake of red meat (RR: 1.2; 95% CI 1.1–1.3) and processed meat (RR: 1.3; 95% CI 1.2–1.4) and SSB (RR: 1.3; 95% CI 1.2–1.4) was associated with a higher risk. Also, a daily intake of 2-3 servings of wholegrains, 2-3 servings of fruits and 3 servings of dairy was associated with a 42% lower T2DM risk, compared to no consumption; and a daily intake of 2 servings of red meat (170g), 4 servings of processed meat (105g) and 3 servings of SSB (750 ml), compared to no consumption was associated with a three-fold higher risk of T2DM (Schwingshackl et al., 2017). Similar findings have been reported in other systematic reviews and meta-analyses of prospective observational studies (Aune et al., 2013a, Imamura et al., 2015, Pan et al., 2011, Aune et al., 2013b and Wang et al., 2016). An inverse association was found between dairy consumption and incident T2DM in a large prospective study (Forouhi et al., 2015). A systematic review of prospective cohorts by Carter P et al (2010) showed that greater consumption of green leafy vegetables was associated with a 14% (hazard

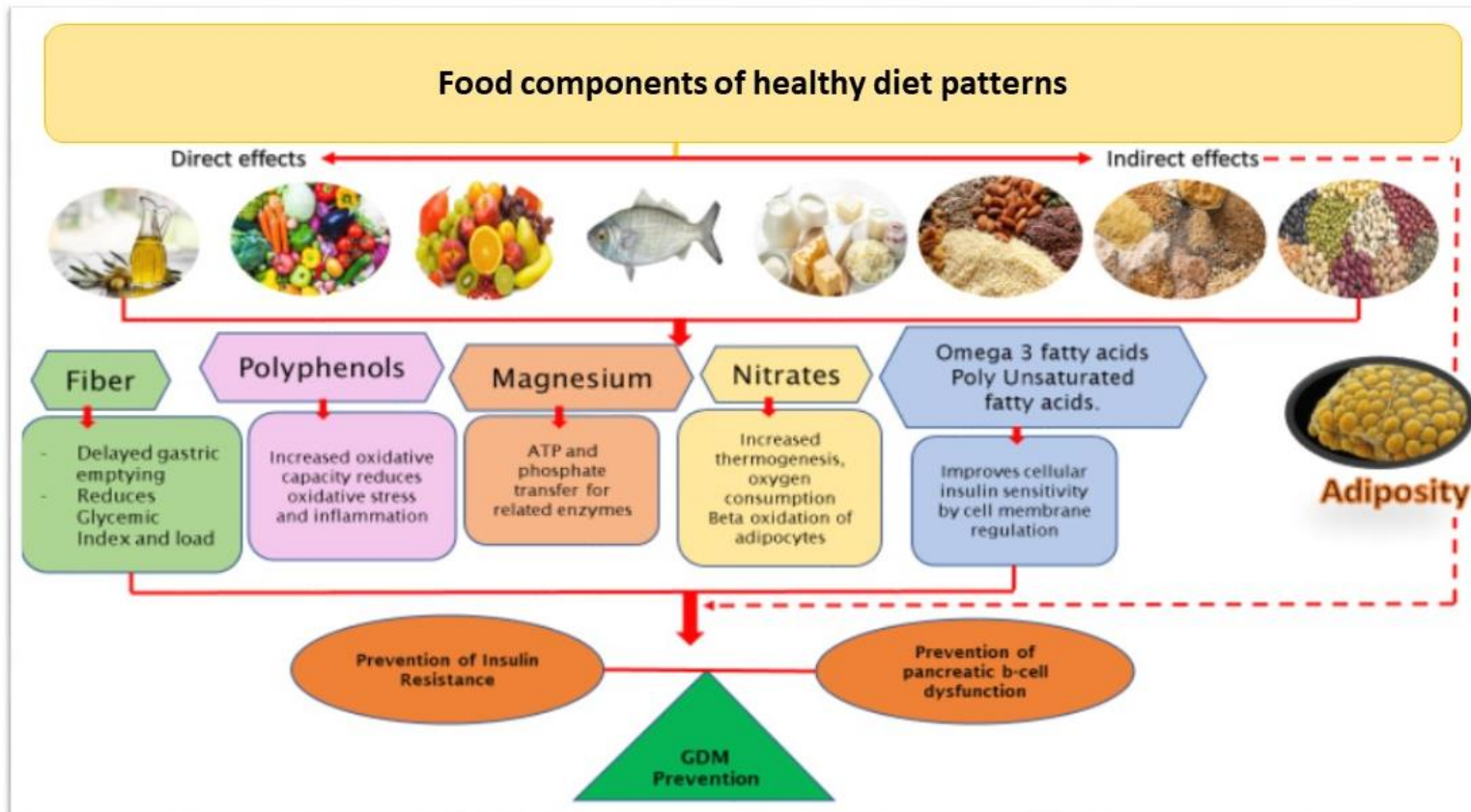
ratio 0.86, 95% confidence interval 0.77 to 0.97) risk reduction ($p=0.01$). A systematic review of dietary pattern studies by Jannasch et al., 2017 of 16 cohorts found that a Western pattern (high intake of red and processed meat, sweets, savoury snacks, and refined grains) was associated with a higher T2DM risk (RR: 1.44; 95% CI: 1.27-1.62). A dietary pattern with high intake of fruits, vegetables, legumes, fish, poultry and whole grains was associated with lower risk of T2DM (RR: 0.84; 95% CI: 0.77-0.91).

Experimental evidence: A systematic review and metanalysis of combined diet and physical activity interventions to prevent T2DM in healthy adults and those with impaired glucose tolerance concluded that a healthy diet and lifestyle can prevent and delay T2DM (Hemmingsen et al., 2017). Dietary advice was heterogeneous and included reduced intake of processed foods, refined grains, sugar, red meat, energy, fat and portion size, increased intake of fibre, fruits and vegetables, wholegrains, and legumes, and less processed foods with or without increased physical activity (Forouhi et al., 2018). The evidence base is larger and less heterogeneous for T2DM as an outcome than for GDM. More studies have shown dose-response relationships of food intakes with T2DM risk, and the evidence is more consistent. For example, fruits and vegetable protein have been associated with both higher and lower GDM risk in different populations, but are consistently associated with lower T2DM risk. However, there is overall agreement between the diet-GDM and diet-T2DM evidence.

1.5.7. Potential mechanisms by which diet may prevent GDM and T2DM

The idea that diet is protective against the development of diabetes is biologically plausible (figure 1.5). High intakes of vegetables, fruits, whole grain cereals, legumes, fish, dairy, nuts and seeds, leads to abundant ingestion of key functional macro and micronutrients including fibre, polyphenols, magnesium, calcium, nitrates and unsaturated fatty acids (long chain polyunsaturated fatty acids [PUFAs]). These dietary components enable a gradual and controlled blood glucose rise, which leads to less adiposity. GDM prevention may be due to reduced insulin resistance and beta-cell dysfunction by the overall diet and individual dietary components (Mitjavilia et al., 2013; Schroder, 2007 & Tsoukas et al, 2013).

Figure 1.5: Potential mechanisms of healthy diet patterns to prevent GDM and T2DM



Literature used for constructing the diagram: Mitjavilia et al., 2013; Chandalia et al., 2000; Schroder, 2007 & Tsoukas et al., 2013.

1.6. Blood micronutrient levels and GDM

Blood micronutrient levels are a reflection of dietary intakes and sufficient levels act as biomarkers of healthy diets. Blood micronutrient sufficiency is contributed to by various food groups including cereals, legumes, fruits, vegetables, nuts and animal foods including dairy, eggs, fish, poultry and meat (Shenkin et al., 2006). Observational and intervention studies have shown that adequate blood levels of vitamins - B12, D, C, magnesium and selenium are associated with a lower GDM risk, while higher folate and iron levels have been associated with a higher GDM risk (Silva-Zolezzi et al., 2017). However, the overall evidence is inconsistent due to the heterogeneity of studies (Misra et al., 2019).

1.6.1. Associations between blood folate and B12 levels and GDM risk

Evidence from three studies has shown an inverse association between blood B12 levels and GDM risk (Krishnaveni et al., 2009; Sukumar et al., 2016 & Lai et al., 2018). Two studies have shown a positive association between blood folate levels and GDM risk (Lai et al., 2018 & Xie et al., 2019).

In a retrospective observational study in Mysore (India) among 774 women, B12 deficiency (plasma B12 <150 pmol/L) was associated with a higher GDM risk (OR: 2.14, 95% CI: 1.11-4.13) and greater adiposity (OR: 2.1, $p < 0.001$). Folate concentration was not associated with adiposity or GDM, but among B12 deficient women the risk of GDM was increased at higher folate concentrations (Krishnaveni et al., 2009). In a retrospective case-control study of 344 women (143 with GDM) in the UK, B12 deficiency (serum B12 levels <150 pmol/L) was associated with higher GDM risk (OR: 12.59, 95% CI: 1.35-4.98, $p = 0.004$) and adiposity (OR: 2.40, 95% CI: 1.31-4.40, $p = 0.004$), after adjusting for confounders including ethnicity and others (Sukumar et al., 2016). Folate deficiency was not associated with GDM or adiposity, but among non-GDM women, the newborns of those in the lowest and highest quartiles of B12 and folate levels respectively had a higher risk of macrosomia (RR: 5.3, 95% CI: 1.26-21.91, $p = 0.02$). Both studies

indicated that BMI partly mediated the association between B12 and GDM risk.

A prospective cohort of Malay, Chinese and Indian women in Singapore (n=913), found that higher plasma folate levels were associated with a higher GDM risk (OR: 1.29, 95% CI: 1.00-1.60) and higher adiposity. B12 levels were inversely associated with GDM risk (OR: 0.81, 95% CI: 0.68-0.99). Also, GDM was more prevalent among women who were B12 deficient and had the highest folate levels (OR: 1.97, 95% CI: 1.05-3.68). This was after adjusting for confounders including BMI and ethnicity and others (Lai et al., 2018). In a case-control study of 282 women in China, red blood cell folate concentration was higher in GDM women, compared to controls (RR: 1.16, 95% CI: 1.03-1.30, p=0.01; median folate concentrations among GDM and non-GDM women were 1554.0 and 1478.5 nmol/L respectively) (Xie et al., 2019). One study reported that cord blood levels of babies born to GDM women, collected after delivery, had higher folate than those of non-GDM women (Barzilay et al., 2018).

There are a number of mechanisms by which B12 and folate may play a role in the development of GDM. Both micronutrients are needed for cellular reactions called one-carbon metabolism (Rush et al., 2014). They are required for synthesis of proteins, lipids and DNA and have a role in gene expression (Finer et al., 2014). B12 acts as a coenzyme and plays an important role in lipid metabolism for converting methyl malonyl CoA to succinyl CoA, limiting fatty acid oxidation and stimulating lipogenesis. Therefore, low B12 levels may lead to lipid metabolism dysfunction, inflammation and insulin resistance (Adaikalakoteswari et al., 2015). B12 deficiency may alter one-carbon metabolism, leading to lower methionine levels and reduced protein synthesis, which may hinder muscle development, leading to diabetes (Yajnik et al., 2010). It has been shown in an Indian study that low maternal vitamin B12 and high folate in pregnancy was associated with adiposity and insulin resistance in the offspring at 6 years (Yajnik et al., 2008a).

1.6.2. Association between blood vitamin D levels and GDM risk

A systematic review of 87 observational studies done in different economies and latitudes across the globe (N = 55,859) and 25 randomised controlled trials (RCTs) (N=2,445) found that, lower vitamin D levels during pregnancy were associated with a higher GDM risk (OR: 1.85, 95% CI: 1.47, 2.32) (Zhang et al., 2018). Two observational studies in India have found similar results. In Mysore, among 559 women, serum 25-hydroxyvitamin D levels were not associated with GDM risk, but were inversely associated with 30-minute glucose concentrations ($p=0.03$) and higher fasting proinsulin levels ($p=0.04$) (Farrant et al., 2009). Another study in Bangalore with 392 women found that women in the lowest quartile of plasma total vitamin D level had double the risk of GDM, compared to women in the other quartiles (OR: 2.32, 95% CI: 1.10, 4.91) (Dwarkanath et al., 2019). However, case-control studies from India, the UK and United States and an RCT in Iran had mixed findings (Zhang et al., 2008; Baker et al., 2012; Makgoba et al., 2011 & Tehrani et al., 2017).

Vitamin D's role in glucose homeostasis may be through increasing insulin sensitivity in liver, muscle and adipose tissue by stimulating the expression of insulin receptors thus regulating glucose uptake (Soheilykhah et al., 2010). Vitamin D may indirectly influence glucose homeostasis by regulation of intercellular calcium, which is required for insulin-mediated glucose uptake (Poel et al., 2012).

1.6.3. Association between blood ferritin levels and GDM risk

Iron homeostasis is strictly controlled, and absorption depends on the body's stores and availability through diet (Hansen et al., 2014). Iron is more bio-available from heme than non-heme sources. Non-heme iron is obtained from plants and supplements while heme iron is found in animal foods including poultry, meat and fish (Hallberg et al., 1979). Clinical biomarkers of iron status include blood iron, haemoglobin, ferritin, transferrin, transferrin saturation and serum transferrin receptor. No one biomarker can completely predict iron status (Open Global, 2019). Ferritin is a storage protein and also an acute phase reactant that is elevated during inflammation, hence to interpret

serum ferritin, another inflammation marker called CRP (C-reactive protein) is useful (OpeN Global, 2019). Serum transferrin receptor (sTfR) and the ratio of sTfR and ferritin are more sensitive markers of iron status than ferritin alone as they are not influenced by inflammation.

A recent meta-analysis (N=44,110), based on 16 studies from Iran, Turkey, Lebanon, China, Spain, USA, Australia, Greece and Denmark) investigated the association between iron biomarkers and GDM, and found that higher ferritin was associated with higher GDM risk (adjusted OR: 1.6, 95% CI: 1.2, 2.1) (Kataria et al., 2018). However, studies investigating sTfR (Khambalia et al., 2016; Rawal et al., 2017 & Bowers et al., 2016) and the ratio of sTfR and ferritin (Alam et al., 2018) have not shown any associations with GDM. A possible reason for this difference from ferritin could be because sTfR levels usually rise only in the presence of functional iron deficiency (Kataria et al., 2018). There have been no studies from India relating iron status to GDM.

Iron is required for foetal development, and low maternal iron stores are associated with an increased risk of neonatal morbidity and pre-term birth (Milman et al., 2008). On the other hand, high iron stores have been associated with adverse pregnancy outcomes such as low birth weight, stillbirth, pre-eclampsia and GDM. This may be because high iron levels make the blood more viscous, reducing placental perfusion (Iqbal & Ekmekcioglu, 2017). Iron is associated with oxidative stress as it acts as a catalyst to generate hydroxyl free radicals causing cellular damage (Zein et al., 2015).

1.7. Summary of evidence and knowledge gaps

1.7.1. Diet and GDM

Systematic reviews of observational studies suggest that improving diet before and during pregnancy may have a role in preventing GDM. Overall, the observational evidence linking diet and GDM risk is in agreement with findings on diet-T2DM risk (Zhang & Ning, 2011; Schoenaker et al., 2016a). The overall picture of various diet exposures

and GDM risk (nutrients, foods, food groups and diet patterns) convey some similar findings. For instance, red meat, which is high in fat, cholesterol, heme iron and animal protein and is a component of unhealthy diet patterns, is associated with higher GDM risk. Refined cereals lack dietary fibre and are characteristic of unhealthy diet patterns associated with higher GDM risk. Diet patterns, including the Mediterranean, DASH, aHEI as well as prudent or traditional patterns, were associated with 15-38% lower GDM risk, reported by a recent meta-analysis (Mijatovic-Vukas et al., 2018). Common elements of healthy diet patterns include higher intakes of fruits and vegetables, wholegrain cereals, legumes, nuts; and shared features of unhealthy diet patterns include higher intake of sugar, red and processed meat and fried & food. Adiposity may act as a mediator of dietary effects on GDM risk, and most studies have not treated BMI as a mediator. A few studies that have treated BMI as a mediator, report that the lower GDM risk associated with healthy diet patterns such as the Mediterranean diet, could be mediated through effects of BMI on insulin resistance (Schoenaker et al., 2016b).

Evidence from intervention studies is superior to observational evidence in establishing causality. Not many individual large trials have found an effect of lifestyle interventions (diet and PA) in preventing GDM (Dodd et al., 2014; Bain et al., 2015 & Poston et al., 2015). However, Cochrane systematic reviews have reported poor to moderate evidence that diet and activity interventions reduce GDM risk (section 1.5.5, pages 35 - 38). Overall, there is a lack of evidence relevant to LMICs like India.

1.7.2. Blood micronutrients and GDM

Deficiency of vitamin B12, vitamin D and iron are common among reproductive aged women in India (Pathak et al., 2004). These micronutrients are commonly prescribed as supplements during pregnancy (Seshadri, 2001). Vegetarianism is common in India, where animal foods rich in these micronutrients are not frequently consumed. Insufficient dietary intakes that may be related to SES, religion and education are the causes of iron and B12 deficiencies in

India (Seshadri, 2001).

Folate tablets distributed universally to pregnant women in India contain 5000 µg, when the recommendation is 600 µg (WHO, 2005). The upper tolerable limit of 5000 µg is recommended only for women with a history of neural tube defects (WHO, 2005). Maternal one carbon metabolism imbalance (due to low vitamin B12 and high folate status) and high blood glucose may be an important contributor to adiposity and insulin resistance, and some have suggested that it may be responsible the rise in 'diabetes-adiposity' in India (Yajnik & Deshmukh, 2008b).

A review investigating the relationship between supplements and GDM found that synthetic supplements including vitamins - B12, D, B6, ascorbic acid, magnesium, manganese, zinc, selenium, zinc, omega 3 fatty acids, probiotics and myo-inositol may have the potential to prevent GDM. Folic acid and iron supplements have been linked with higher GDM risk, although they are recommended in pregnancy. However, this is supported by insufficient evidence, with studies of small sample sizes for each nutrient, done in few populations limiting generalizability of findings (Plows et al., 2009).

As described above, systematic reviews have indicated that both high iron levels and vitamin D deficiency may increase GDM risk (Kataria et al., 2018 & Zhang et al., 2018).

1.7.3. Knowledge gaps

Future public health interventions need large prospective observational studies, particularly studying the peri-conceptional diet. No observational studies until now have assessed the diet-GDM association in India. A few studies in India have studied the association between blood levels of folate, B12 (Krishnaveni et al., 2009) and vitamin D (Farrant et al., 2009 & Dwarkanath et al., 2019) and GDM risk. None have studied ferritin status and GDM risk. Therefore, my thesis will address these important knowledge gaps.

1.8. Aims and objectives of my PhD thesis

My PhD project, the Bangalore Nutrition Gestational diabetes LifeStyle Study (BANGLES) aims to study dietary factors and blood micronutrient levels as risk factors for gestational diabetes mellitus in India. The main objectives are to examine:

- **associations between women's peri-conceptional diet with the risk of developing GDM. The dietary exposures include food groups and diet patterns.**
- **associations between blood micronutrient levels (plasma folate, vitamin B12 and vitamin D and serum ferritin) determined in early pregnancy with the risk of developing GDM.**

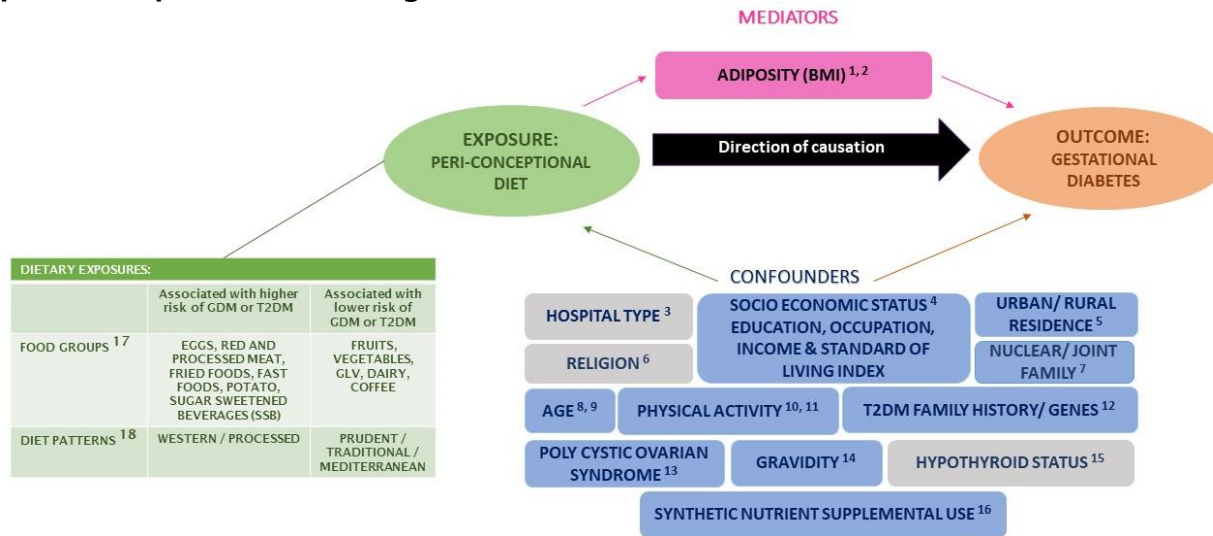
I will examine these associations according to an evidence-based framework or concept diagram, depicting the potential causal associations of my exposures (diet & blood micronutrient levels) with the outcome (development of GDM), and the various factors influencing them.

1.9. The Concept diagram

The concept diagram (figures 1.6 and 1.7, pages 49 - 50) is drawn from the above literature linking nutrition with GDM. Diet is multifaceted and represented as food groups and diet patterns. Blood micronutrients include selected nutrients, folate, B12, ferritin, and vitamin D. Diet and blood micronutrient level exposures may be influenced by various population characteristics, any of which may potentially confound the association between nutrition and GDM (figures 1.6 and 1.7). For example, religion influences meat intake: while Muslims, Christians and many Hindus eat meat, Jains and strictly orthodox Hindus do not. Dietary choices are also based on awareness and affordability, which are related to education and socio-economic status (SES), and on the availability of foods, which is related to urban or rural residence and a joint or nuclear family type. Adiposity (BMI), age, and physical activity may also determine dietary choices. Blood

micronutrient status is influenced by gestational age (haemodilution is maximum between 24-28 weeks), season and sunlight exposure (vitamin D), in addition to other population characteristics shown in the concept diagram. Adiposity (BMI) may play a role in nutrient absorption and utilisation. Evidence suggests that age, gravidity, PCOS and thyroid status, and family history of T2DM are risk factors for GDM, but may be associated with the exposures as well. Factors that influence both exposures and outcome may be potential confounders of the nutrition-GDM relationship. It is important to understand the associations of these population characteristics with my exposure and outcome, and adjust for these in my final analysis, to clarify the exposure-outcome associations. The causal association between diet and GDM may be mediated by adiposity (e.g. an unhealthy diet leads to greater adiposity or BMI, which leads to GDM).

Figure 1.6: A concept diagram exploring causal associations between peri-conceptional diet and gestational diabetes mellitus

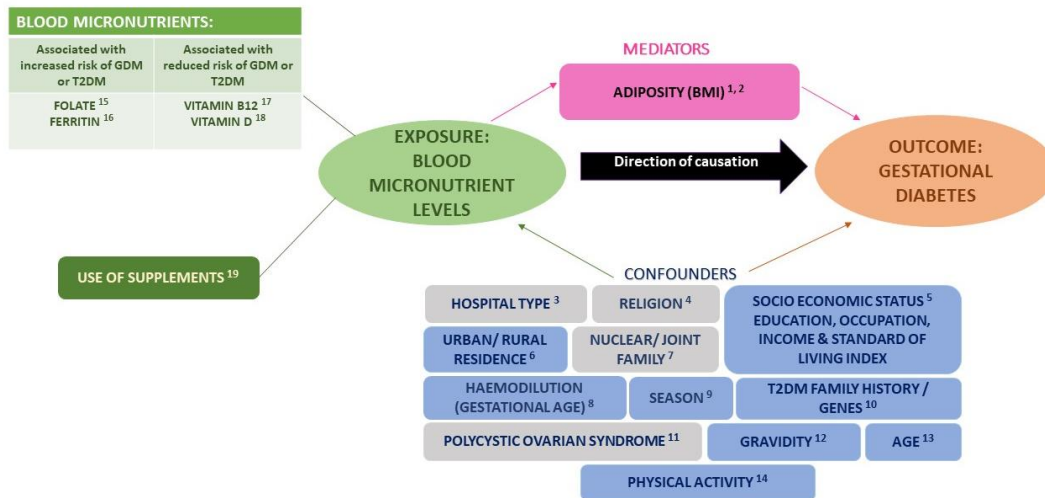


*Population characteristics in blue boxes treated as confounders in published diet-GDM studies.

*Additional population characteristics in grey boxes considered as confounders in BANGLES.

¹ Diet: Radhika et al., 2008, Lilienthal & Lauren, 1995, Chopra et al., 2012; ² GDM: Hill et al., 2005, Mandal et al., 2011, Gopalakrishnan et al., 2015; ³ Hospital types were different in SES and many other characteristics based on observations; ⁴ Mozaffarian et al., 2018, Vaz et al., 2005, Mayén et al., 2014, Agrawal et al., 2019, Chopra et al., 2012; ⁵ Bowen et al., 2011; ⁶ Kehoe et al., 2014, Lodha et al., 1990; ⁷ Biggers et al., 2014; ⁸ Diet: observed from experience; ⁹ GDM: Hill et al., 2005, Seshiah et al., 2008, Xiong et al., 2001; ¹⁰ Diet: observed from experience; ¹¹ GDM: Iqbal et al., 2007; ¹² Solomon et al., 1997, Seshiah et al., 2008; ¹³ Wang et al., 2013; Joham et al., 2014; ¹⁴ Seshiah et al., 2008, Rajput et al., 2014; ¹⁵ Rawal et al., 2018; ¹⁶ Bo et al., 2009, Li et al., 2019 & Cheng et al., 2019; ¹⁷ Eggs: Qiu et al., 2011a, Red & processed meat: Bao et al., 2013, Zhang et al., 2006a, Qiu et al., 2011b, Fried & fast food: Bao et al., 2014, Dominguez et al., 2014, Farnetti et al., 2011, Potato: Bao et al., 2016, SSB: Chen et al., 2009, fruits: Schwingshackl et al., 2017, Vegetables: Mirmiran et al., 2019, Green leafy vegetables: Carter et al., 2010, Dairy: Forouhi et al., 2015, Coffee: Adeney et al., 2007, Hinkle et al., 2015; ¹⁸ Western or processed diet pattern: Sedaghat et al., 2017, Schoenaker et al., 2015, Zhang et al., 2006a, Donazar-Ezcurra et al., 2017, Prudent/ traditional/ Mediterranean pattern: Schoenaker et al., 2015, Tobias et al., 2012, Zhang et al., 2006a, Tryggvadottir et al., 2016, He et al., 2015 & Karamanos et al., 2014.

Figure 1.7: A concept diagram exploring causal associations between early pregnancy blood micronutrient levels and gestational diabetes mellitus



*Population characteristics in blue boxes treated as confounders in blood micronutrient-GDM studies.

*Additional Population characteristics in grey boxes treated as confounders in BANGLES.

¹ Micronutrients: Krishnaveni et al., 2009, Sukumar et al., 2016; ² GDM: Hill et al., 2005, Mandal et al., 2011, Gopalakrishnan et al., 2015; ³ Hospital types were different in SES and many other characteristics based on observations; ⁴ Kehoe et al., 2014, Krishnaveni et al., 2009; ⁵ Shenkin, 2006, WHO-FAO, 2005; ^{6, 7} differences may be due to variations in dietary intakes, SES and access to foods, no reference available; ^{8, 9} Marwaha et al., 2016; ¹⁰ Solomon et al., 1997, Seshiah et al., 2008; ¹¹ Wang et al., 2013; Joham et al., 2014; ¹² Seshiah et al., 2008, Rajput et al., 2014; ¹³ Micronutrients: Gernand et al., 2016; GDM: Hill et al., 2005, Seshiah et al., 2008, Xiong et al., 2001; ¹⁴ Iqbal et al., 2007; ¹⁵ Lai et al., 2018; ¹⁶ Kataria et al., 2018; ¹⁷ Krishnaveni et al., 2009; ¹⁸ Zhang et al., 2018; ¹⁹ Lindsay et al., 2018.

1.10. Importance and implications of BANGLES for India

Pregnancy care in India has always been associated with cultural beliefs and taboos that may act as barriers to healthy eating. For example, in my own clinical experience, it was common to see families feeding pregnant women excessive calories in the form of sweets and ghee (clarified butter), based on perceptions *that gaining 25 to 30 kilograms for all women is necessary to deliver a healthy baby of 3 kilograms*. This tradition might not have done much harm to women 2-3 decades ago but, in the current day, when a pregnant woman starts her pregnancy with a high BMI (more than 25), and has a high gestational weight gain, it may lead to an increased risk of GDM, (Wolff et al., 2008), postpartum obesity and T2DM (Kim et al., 2002, Lee et al., 2007). Besides, the GDM prevalence is high even in women with a low or normal BMI (Seshiah et al., 2008). GDM is a pressing public health issue, and understanding its prevention is vital in India. BANGLES is the first study to investigate diet patterns in relation to GDM in India, and its findings may be valuable for future interventions and development of food based dietary guidelines for reproductive aged women. Such women are exceptionally motivated to seek and follow diet and lifestyle recommendations. Pregnancy is a short phase of nine months but is marked by an intensified awareness of health. It is undoubtedly an impactful stage to intervene and introduce healthful behaviours that might extend beyond pregnancy to further prevent T2DM, in the mother and baby (Tobias et al., 2012). In addition, the findings may be applicable for developing GDM prevention strategies in migrant Indian women in the UK and USA or elsewhere who require culturally appropriate advice, as studies have identified this gap as a challenge that immigrant women with GDM face (Bandyopadhyay et al, 2011). Globally, policy makers have not paid enough attention to GDM, but in order to tackle the economic burden of non-communicable diseases, a top priority should be to make efforts towards improving the nutritional health of mothers, which will also be the stepping stone towards achieving the Sustainable Development Goals (Binns et al., 2017 & United Nations System Standing Committee on Nutrition, 2017).

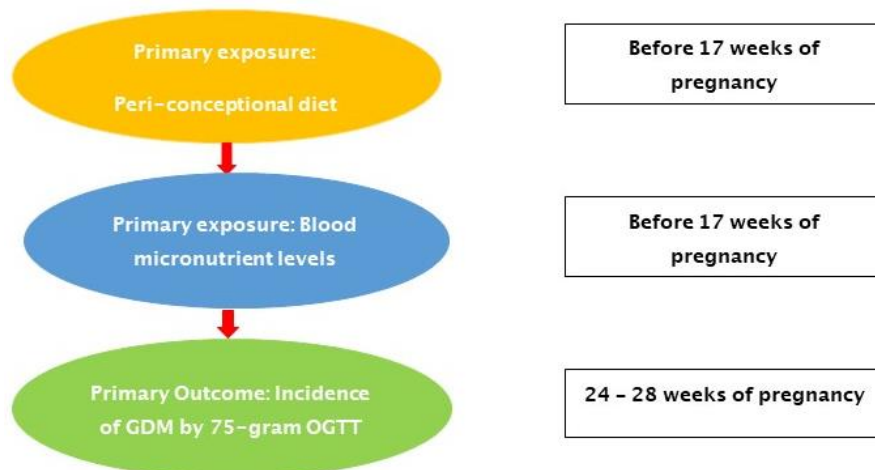
Chapter 2

Methodology

2.1. BANGLES study design in brief

The BAngalore Nutrition Gestational diabetes LiFEstyle Study (BANGLES) is a prospective observational study in Bangalore, India. Its aim was to investigate if pregnant women's peri-conceptional diet, and blood micronutrient levels in early pregnancy, predict the risk of gestational diabetes mellitus (GDM). The primary exposure was a recall of peri-conceptional diet assessed in early pregnancy (using a food frequency questionnaire) and blood micronutrient levels in early pregnancy namely: plasma folate, vitamin B12, vitamin D and serum ferritin. The primary outcome was GDM, diagnosed using a 75-gram Oral Glucose Tolerance Test (OGTT) at 24–28 weeks' gestation according to WHO 2013 criteria. Other information on the women's health, culture, socio economic status and physical activity were recorded using questionnaires. We recruited 785 out of a target of 1000 women across low, middle and high-income groups. Inclusion criteria were: a singleton pregnancy, <17 weeks' gestation, no previous history of diabetes, and an intent to stay in Bangalore until their 28th week of pregnancy (figure 2.1).

Figure 2.1: Exposures and outcomes in BANGLES



2.2. Study setting

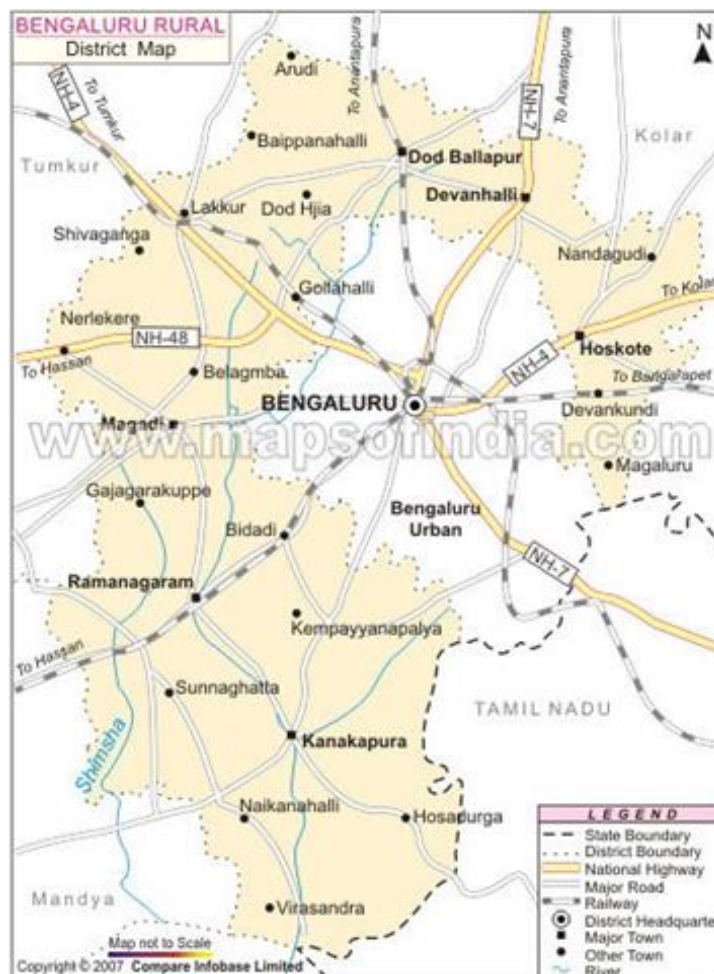
Bangalore, India

Bangalore (Bengaluru) is the capital of the southern Indian state of Karnataka (figure 2.2) and has a population of 8.5 million, after considerable recent expansion (Census of India, 2011). It includes urban and rural districts (figures 2.2, 2.3). 78.9% of the population is Hindu, lower than the national average. Muslims comprise 13.9%, similar to the national average. Christians and Jains account for 5.6% and 1.0% of the population, respectively. The city has a literacy rate of 89%. Roughly 10% of Bangalore's population live in slums (Census of India, 2011).

Figure 2.2: Location of Bangalore, India



Figure 2.3: Bangalore map showing urban and rural areas



*The central area in white is Bangalore urban and the surrounding yellow shaded area is rural.

The healthcare system in India is very different from the UK. Most people in Southampton would choose Princess Anne Hospital for their antenatal care and delivery. But in Bangalore, and India as a whole, there is a choice of hundreds of hospitals and health care centres. A woman's choice depends on where she lives, income, education and occupation. Highly skilled professionals such as software engineers usually have employee insurance covering maternity care, which enables them to choose hospitals with the best services.

In order to capture patients from a diverse range of socio economic status, I initially chose to set up BANGLES in 3 hospitals: Bangalore Baptist Hospital, Cloudnine Hospitals (two sites) and Vanivilas Hospital, all located in urban Bangalore (figure 2.4).

Figure 2.4: Location of the 3 hospitals in urban Bangalore



Bangalore Baptist Hospital 

Cloudnine Hospital Jayanagar 

Cloudnine Hospital Malleshwaram 

Vanivilas Hospital 

2.2.1. Basis of selecting the 3 hospitals

These hospitals were selected to include study participants representing diverse - socio economic strata, religious and cultural backgrounds, and rural and urban Bangalore (table 2.1, page 63), and to increase my chances of recruiting 1000 pregnant women in an allocated data collection period of 16 months. Other important criteria were that senior clinicians were willing to support the study, that hospital policy was to use a 75-gram glucose tolerance test (OGTT) in all pregnant women, that care was consultant-led, making it more likely that women would stay throughout their pregnancy, and that the hospital laboratory was NABH (National Accreditation Board for Hospitals) and NABL (National Accreditation Board for Laboratory) and ISO9000 accredited, ensuring good quality laboratory testing (NABH &

NABL, 2018). Despite considerable effort, I was ultimately unable to include Vanivilas Hospital as a study centre because of the delay in the hospital's ethics committee's meeting. In the following sections, I have retained some information about Vanivilas Hospital in order to reflect my thinking about the study design, and the effort that I put in to try to include it.

2.2.2. Description of the 3 hospitals

Baptist Hospital (BBH): BBH was established in 1973 as a small makeshift outpatient clinic for rural Bangalore. Today it is a 350 bedded, multi-specialty teaching hospital. The surrounding area has a lake and railway station and is commercially developed, with shopping malls, tech parks, flyovers and educational institutions (figures 2.4 & 2.5). The hospital is partly governed by the Christian Medical College, Vellore and the International Mission Board of the US Southern Baptist Convention (BANGALORE BAPTIST HOSPITALS, 2017). It caters to patients from upper, middle and lower income groups from rural & urban Bangalore. Although relatively inexpensive, it charges patients for obstetric care, and therefore excludes very poor patients.

Cloudnine Hospitals: The two Cloudnine hospitals are 60 bedded, single-speciality hospitals providing only obstetrics and neonatology services. Both locations are well developed residential and commercial areas, where upper middle and upper income groups live (figures 2.4 & 2.5). Cloudnine is a private hospital group that offers (since 2007) personalized, luxurious health care with maximum privacy, catering mostly to affluent families. Cloudnine also offers parent-craft workshops, lactation support, nutrition advice and physiotherapy (CLOUDNINECARE, 2017).

Vanivilas Hospital: Vanivilas, established in 1935, is a 536 bedded, government hospital, attached to Bangalore Medical College and Research Institute (BMCRI). It is located near a large market in one of the oldest areas of Bangalore (figures 2.4 & 2.5) and offers free and very low cost basic services, catering to the poorest families (BMCRI, 2017).

2.2.3. Key differences between the hospitals

The three hospitals are very different (figures 2.5, 2.6 a, 2.6 b, 2.7 and table 2.1, pages 59 - 63). Baptist Hospital has separate wards for higher, middle and lower income groups. The facilities are comfortable (figures 2.6 a, 2.6 b and 2.7). The cost of delivery ranges between INR 15,000 to 50,000, based on the degree of comfort, and women range in age from 18 to 30 years. There are ~300 deliveries a month. Cloudnine hospitals cater to the most affluent groups. Most women are well educated, have a career, and are older. Cloudnine offers luxurious ward facilities (figures 2.6 a, 2.6 b and 2.7), and consultant-led delivery costs can be as high as GBP 1536 (INR 1,32,864). Vanivilas caters to women with very little education, in unskilled occupations, very low family income, sometimes below the poverty line, from both urban and rural Bangalore. The average monthly income and the cost of delivery are under INR 5000. There are over 920 deliveries a month and the wards are very basic (figures 2.6 a, 2.6 b and 2.7). The maternal age range is 18 – 22 years.

Figure 2.5: Photographs of the areas close to the three hospitals

a. Traffic around Baptist Hospital in Hebbal.



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b. A residential complex near Cloudnine Hospital in Malleshwaram.



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c. A commercial complex in Jayanagar



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d. Wholesale market with makeshift tents in city market near Vanivilas Hospital



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Figure 2.6 a: Outside view of the 3 hospitals

Bangalore Baptist Hospital



Cloudnine Hospital



Vanivilas Hospital



Figure 2.6 b: Inpatient wards of the 3 hospitals

Bangalore Baptist Hospital



Cloudnine Hospital



Vanivilas Hospital



Figure 2.7: Outpatient departments of the 3 hospitals

Baptist Hospital



Cloudnine Hospital



Vanivilas Hospital



Table 2.1: Key differences between the 3 hospitals (figures and cost estimates taken in May 2017)

	Bangalore Baptist Hospital	Cloudnine Hospital	Vanivilas Hospital
Location	North Bangalore	South Bangalore	South & Central Bangalore
Type of hospital	Multi-specialty, mission and teaching hospital.	Single-specialty, private and corporate hospital.	Single-specialty and Government hospital.
No of beds	350	60	536
Peak maternal age group	18 – 30 years	30 – 34 years	Under 18 to 25 years
Socio-economic strata catered to	Lower, middle and high income group	High income group	Lower income group and Below Poverty Line
Average monthly Income of patients in the hospital	INR 15,000 – 50,000 GBP 173.27 - 568.24	INR 75,000 and over GBP 577.58 and over	Under INR 5000 Under GBP 57.76
Caters to regions	Urban and rural Bangalore	Urban Bangalore	Urban and rural Bangalore and nearby places to Bangalore
Total no of deliveries per month	300 and over	150 and over	920 and over
Annual OPD patients seen	30,000 (approximate)	2000 (approximate)	48,899 (approximate)
Average cost of delivery to the patient	INR 15,000 – 50,000 GBP 173.27 – 568.24	INR 75,000 – 1,35,000 GBP 853.84 - 1536.91	No charges for below poverty line (BPL) card holders and nominal charges for others.

2.3. BANGLES study design

2.3.1. Dietary data collection

Dietary behaviour was assessed using a 224-item food frequency questionnaire (FFQ) (Appendix F, page 299) and 24-hour recall (Appendix E, page 296) to capture long and short term dietary habits respectively. The FFQ was administered twice, firstly when women were recruited at their first antenatal visit before 17 weeks' gestation. The reference period was a typical month around the participant's time of conception. Most women discover that they are pregnant between 2-4 weeks after conception so we asked women to think back to what they were eating during the month before they knew they were pregnant. A second FFQ was administered at 24-28 weeks' gestation, at the time of their OGTT. The reference period was the preceding month, and its purpose was to study changes in diet between peri-conception and late pregnancy. FFQs are useful for measuring long-term diet, to capture habitual intake of foods and food groups, in order to explore dietary patterns, diet diversity and develop dietary indices. (Cade et al., 2004). A 24-hour recall was conducted at both time points, to have a second dietary assessment, to provide data to validate the FFQ (Hébert et al., 2014).

2.3.2. Development of the BANGLES food frequency questionnaire

The 224-item BANGLES FFQ was developed from the Mysore Parthenon Study FFQ (Kehoe et al., 2014). The Mysore Parthenon birth cohort was established to study the prevalence of GDM and its impact on children (Hill et al., 2005). The 136-item Parthenon FFQ was developed in 2007 to assess the diets of children aged 9 years. Diets in Bangalore and Mysore are likely to be similar, because Mysore is also in the state of Karnataka, approximately 150 kilometres from Bangalore. The Parthenon FFQ was modified for BANGLES, following pilot work, for three main reasons: 1) To make it appropriate for pregnant women rather than children. 2) To capture foods consumed by urban women

across different income groups, including 'new age' foods, for example, ready to eat breakfast cereals. 3) These foods were lacking in the Mysore Parthenon FFQ as they were not widely available a decade ago. 4) To be easy to administer.

2.3.3. Pilot work

It is known to be challenging for the interviewer to collect dietary data and for the interviewee to recall their diet. To address this, I conducted pilot work of 500 24-hour recalls among pregnant women in both hospitals (Baptist and Cloudnine). This was mainly to identify frequently consumed foods that were not in the Mysore Parthenon FFQ, and food items appearing more than 5 times were added to the BANGLES FFQ. The FFQ was organised into sections to facilitate data collection.

To ensure consistency of data collection the nutritionists in my team were trained to administer the FFQ in a set manner. I designed a food atlas, showing pictures of foods to assist participants (Food atlas sample in Appendix K, page 325 and figure 2.9, page 70). For common foods like dosa, chapathi, idly, cucumber and non-vegetarian foods, models were made with polystyrene, cardboard and plaster of paris (figure 2.8). A data collection manual in 4 commonly spoken languages (Kannada, Hindi, Tamil and Telugu) was created and used in training, to ensure that we all knew common names in all languages and probed in a uniform manner (sample in Appendix L, page 327). During training, each nutritionist's FFQ administration was recorded using a dictaphone to pick up inconsistencies. An inter- and intra-observer variation study was conducted, which showed good consistency (data not shown).

In order to quantify dietary intakes, an FFQ kit was created with commonly-used household utensils (spoons, cups, plates and glasses), and these were weight- and volume-standardized to quantify portion size (figure 2.8, page 66).

2.3.4. Modifications used for the BANGLES FFQ and their rationale

The pilot 24-hour recalls were used to finalise the BANGLES FFQ, making it culturally appropriate to pregnant women in Bangalore. The following changes were made from the Parthenon FFQ:

Beverages: Nutrition supplement powders containing energy, protein and micronutrients were frequently consumed among pregnant women with milk and were added to the FFQ. The most frequently consumed brands, which vary in their nutritional composition were added.

Figure 2.8: The BANGLES FFQ kit



Powders such as Glucon D (Glucose) and Electrolal (containing salt, sugar and minerals) were frequently consumed in the 1st trimester, by adding to water or tender coconut water. Hershey's chocolate syrup was frequently consumed with milk and eaten with biscuits. In

addition, sugarcane juice, packaged fruit juices, milkshakes, fresh vegetable, non-vegetarian and instant soups were added.

Seasonal fruits: I conducted a market survey in 6 shops in different areas of Bangalore, and found that some fruits (guava, pomegranate, sapota and green grapes) were available throughout the year. Others (raw mango, ripe mango, jackfruit, orange, watermelon, purple grapes, litchi, amla, jamun, plum, custard apple and strawberry) were seasonal (for example, mango was available from March to June). Therefore, I created a separate FFQ section for seasonal foods. Rarely consumed foods like kiwi, avocado and ice apples were added to a probing list of 'other' foods. Seasonal foods were grouped separately in the FFQ and the women were asked how often they consumed them when in season, making it clear they were not consumed all-round the year. Hence, no correction factor was necessary during analysis.

Dried fruits and nuts: Piloting revealed that dried fruits, nuts and seeds are consumed by the current generation of reproductive-aged women that were not consumed a decade ago, and can be termed 'new age foods'. These are marketed as 'super-foods' by the food industry. Figs, prunes, pistachios, apricots, sunflower seeds, pumpkin seeds, flax seeds, groundnuts and walnuts were added to the FFQ.

Rice and wheat foods: The rice and wheat foods sections were combined because they are consumed daily and often together (for example, chapathi and rice). By combining these sections, the nutritionists were able to probe and record the frequency more easily.

Rice foods: Seasoned rice varieties such as tamarind, onion, ghee and lemon rice were coupled in a single group because they are similar in nutritive value, with few calories coming from the seasoning ingredients, and the majority of calories coming from the rice itself. Red and brown rice (unpolished rice varieties) were added as separate items as they vary in nutrient-content. Also, I observed that red rice was a staple food eaten by people from Mangalore and Kerala, while brown rice was eaten by people who are health-conscious or who have relatives at home with diabetes or who stay in rural areas. Rice

vermicelli, rice flakes and puffed rice are similar in nutritive value and hence were coupled together as one item on the FFQ.

Ragi foods: Ragi (finger millet) vermicelli and ragi malt were added, they are perceived as easy to digest and useful to relieve the acidity common among pregnant woman.

Vegetable sides: To this section I added mushroom, green leafy curry and all types of gourd palyas. Drumstick is commonly consumed in curry, and sambhar (a lentil side dish) and was grouped separately. Beetroot, yam and tapioca were coupled together as one FFQ item because they are all root and tuber vegetables of similar nutrient-content.

Ready to eat breakfast cereals: A majority of Indians consume fresh, home-cooked breakfast and traditional foods like idly, dosa, poori, upma, seasoned rice and paratha, but ready to eat breakfast cereals are becoming more popular. Hence a separate section was added for these, including oats, wheat flakes, muesli, bran flakes, corn flakes (plain and with dry fruit) and chia seeds.

Sweet snacks: Popular branded sweet biscuits such as Parle-G, Glucose, Tiger, Marie and Gooday were added as one item. Branded salted and cream biscuits were added as two separate items. Popular sweet dishes like kesaribaath, obattu, barfi, jamun, jalebi, jangir, halwa, kheer, rasgulla, rasmalai, chum chum, champakali and malai sandwich were added. Regional names were used where applicable (for example, obattu is also known as holige in Kannada, boli in Tamil, bobatlu in Telugu and puranpoli in Marathi). To reduce the number of items, sweet dishes with similar nutritive value and ingredients were grouped together. For example, Gulab jamun, jalebi and jangir all contain refined wheat flour and sugar as the main ingredients, and all contain about 150 kilo calories per portion of about 40 grams. Similarly, laddoo and mysore pak contain chickpea flour/besan, sugar and ghee, with both containing approximately 250 kilo calories per portion of 45 grams. Bengali sweets like rasgulla, rasmalai, chum chum, champakali and malai sandwich were grouped together, as they are made of curdled milk and sugar, containing 300 kilo calories per

portion of 68 grams. Western style desserts such as pudding, soufflé, custard and cheese cake were combined together as they all contain about 350 kilo calories and are usually consumed by urban women.

Non vegetarian foods: Non-vegetarian foods including chicken, fish and mutton in their various forms such as curry, sambhar, fry and cutlets were added. Dry fish was added separately. Seafood including prawn, crab and shell fish and organ meat including liver, brain and kidney were added separately. Egg, as omelette and in the boiled form, were added with and without the yolk (commonly not eaten for religious reasons or personal choice).

Chutneys: Coconut and groundnut chutneys were frequently consumed with dosa, idli, rice, chapathi, puri, upma and bhajji, and so were added to the FFQ.

Sugar and jaggery: Jaggery (a traditional concentrated product of sugar cane juice) was added, as it is used as a substitute for sugar, sometimes with tea, coffee, milk or by itself. Items originally on the Parthenon FFQ including sugar with idli, dosa, puri and chapathi were removed because these are usually consumed by children.

Fast foods: Fast food chains such as Burger King, KFC, McDonalds and Pizza Hut are now popular in India. Pizza and burger were categorised separately as vegetarian and non-vegetarian foods respectively.

Savoury snacks: Savoury snacks commonly available in bakeries, shops, and restaurants such as Gobi Manchurian, pakoda, bhajji, bonda, samosa, chips (potato/plantain), puff, chakli, murukku and kodbale were added. As for sweet snacks, similar ingredient and calorie items were grouped together to reduce the size of the FFQ. For example, pakoda, bhajji, bonda and samosa all contain chickpea flour, are deep fried in oil and contain about 300 kilo calories per serving. Urad vada was a separate FFQ item as it was made at home or bought from takeaway-restaurants, and frequently eaten for breakfast on weekends.

Milk products: Paneer (cottage cheese) tikka, curry, grated processed cheese, mozzarella and cheese spread were added under dairy

products. These were not in the Mysore Parthenon FFQ but are commonly consumed in Bangalore.

A picture of each food, cooked in its various forms, was included in the FFQ atlas (appendix C, and figure 2.9).

Figure 2.9: Avrekalu (green bean) as shown in the food atlas



2.3.5. Supplements

Information on the use of nutritional supplements (iron, folate, calcium-vitamin D, B12 and energy-protein) were recorded, because they alter blood nutrient levels substantially (Shenkin, 2006). The dose, frequency, brand name or generic name of nutraceutical, wellness supplements and medications were documented from the obstetrician's prescription at both the first and second stages of the study.

2.3.6. Blood micronutrients

I included plasma folate, vitamin B12 and D and serum ferritin in early pregnancy as exposures. I measured these blood nutrients, at 8-16 weeks and this period was chosen to have a uniform window for haemodilution. Also, because of a limited budget, we could not do

blood micronutrient analysis for 304 women (all women with GDM and an equal number of their age and BMI matched controls) afford in all women, so measured them in all women with GDM and an equal sample of women without GDM matched for age and BMI (described in detail in section X). This will also have the benefit of making the power calculation more intelligible. 75-gram OGTT and diagnostic criteria for GDM.

2.3.7. 75-gram OGTT and diagnostic criteria for GDM

I chose the 75-gram OGTT and WHO 2013 criteria (WHO 2013; table 2.2) for defining GDM. It is recommended by WHO for diagnosing GDM globally and has been validated in Indian populations (Surapaneni et al., 2013). It is easier for patients than a 100-gram OGTT.

Table 2.2: The WHO 2013 diagnostic criteria for GDM

Blood glucose value	Cut-offs
Fasting plasma glucose	5.1-6.9 mmol/L or 92 -125 mg/dl
1-h post 75 g oral	>10 mmol/L or 180 mg/dl
2-h post 75g oral glucose load	8.5 – 11.0 mmol/L or 153-199 mg/dl

2.3.8. General health Information

Several health factors are independent predictors of GDM and/or influence diet and blood micronutrient levels and therefore I collected information on these. Increasing age has a direct linear relationship with GDM risk (Terence et al., 2006). Multi-gravid women are known to have a higher risk of GDM than primigravid women (Schwartz et al., 2015). Assisted reproductive techniques (ART) like ovulation induction (OI), in vitro fertilization (IVF) and intra uterine insemination (IUI) are associated with a higher risk (Zhang et al., 2015). Polycystic ovarian syndrome (PCOS) and thyroid problems are hormonal imbalances known to alter insulin function and increase the risk of GDM (Yu et al., 2016). A family

history of T2DM has also been positively associated with risk of GDM (Retnakaran et al., 2007). Hence all these were recorded.

Gestational age at recruitment was ascertained by the last menstrual period (LMP) date, which was recorded from the antenatal records and cross checked with the participant. The reason for choosing LMP was for convenience, since we sometimes enrolled participants before a dating scan. Gestational age was recorded to follow up women for their glucose tolerance and birth outcomes.

BMI is a proxy estimate of adiposity and a higher BMI is associated with a higher risk of GDM (Mandal et al., 2011). Weight and height at recruitment were measured, and pre-pregnancy weight and lowest adult body weight were recorded by recall (Appendix D, page 292).

2.3.9. Socio Economic Status (SES)

SES is an important determinant of health and the risk of GDM differs across socio economic strata. It is challenging, but critical, to measure socioeconomic status, which comprises different elements including education, income, location and household assets. To measure SES, we used the Standard of Living Index from the National Family Health Survey of India (NFHS) 3, which creates a score based upon details of the participant's house and assets (NFHS 3, 2005-06). We added additional assets to update the list, including air conditioner, washing machine, mobile phone, computer, broadband internet and plasma TV. Most of these appear in the NFHS 4 questionnaire (NFHS 4, 2014-15) but we did not use this because its scoring system is not yet available. In addition to the SLI questionnaire we asked questions about the participant's occupation and education, the main breadwinner's occupation and education, and family income (Appendix G, page 316).

2.3.10. Physical Activity

Low physical activity (P.A) is associated with an increased risk of GDM (Aune et al., 2016). We measured PA using the International Physical Activity Questionnaire (IPAQ) short version (IPAQ group, 2005) which has been validated globally (Craig et al., 2003). We also assessed screen time (television, mobile phones and laptops), which is an important predictor of sedentary behaviour according to a systematic review (Tremblay et al., 2009) (Appendix H, page 320).

2.4. Power and sample size calculation

Based on a sample size of 1000 women, and assuming a prevalence of GDM of 10% in the poorest third of women, 20% in the middle third and 30% in the most affluent third, it was calculated prior to the study that I would have 80% power at the 5% significance level, to detect a difference of 0.22 standard deviations (SD) in the weekly frequency of intake of a specific food group or diet pattern between women who do and do not develop GDM (tables 2.3 & 2.4). I would have the same power to detect a 0.28 SD difference in blood nutrient levels (table 2.4). This calculation was made by Prof Clive Osmond, senior statistician in the MRC Lifecourse Epidemiology Unit.

Table 2.3: Estimated number of women with GDM with/without blood analysis status among different income groups

By income (GDM prevalence)	GDM	No GDM with blood analysed	No GDM with blood not analysed	Total
HIG (30%)	A=100	D=100	G=133	A+D+G=333
MIG (20%)	B=67	E=67	H=200	B+E+H=334
LIG (10%)	C=33	F=33	I=267	C+F+I=333
All	A+B+C=200	D+E+F=200	G+H+I=200	A to I = 1000
HIG - High Income group; MIG - Middle Income Group; LIG - Low Income Group				

Table 2.4: Difference detectable with 80% power for diet and blood micronutrient variables (continuous) measured in standard deviation units, using a test at the 5% level of statistical significance

Comparison		Setting	Sample Sizes	Detectable
A+B+C v D+E+F	Blood analysis	All Income	200 v 200	0.28
A v D		HIG	100 v 100	0.39
B v E		MIG	67 v 67	0.48
C v F		LIG	33 v 33	0.68
A+B+C v	FFQ analysis	All Income	200 v 800	0.22
A v D+G		HIG	100 v 233	0.33
B v E+H		MIG	67 v 267	0.38
C v F+I		LIG	33 v 300	0.51

2.5. Ethical approval

I applied to the Ethics Committees (EC) of Baptist, Cloudnine and Vanivilas Hospitals. Both Cloudnine and Baptist gave approval by April 2016. Ethics applications to my academic hosts (Faculty of Medicine, University of Southampton and CSI Holdsworth Memorial Hospital, Mysore) were made and approved. In addition, I also applied to the HMSC Health Ministry Screening Committee, Indian Council of Medical Research (ICMR), Government of India and got approval. This permission is required for any research involving a foreign collaboration. One EC insisted that if a participant's habitual diet was of very poor quality, it would be unethical not to intervene. To address this, I agreed to incorporate a single session of nutrition counselling to all the women in the study about healthy eating practices during pregnancy.

The ethics committee at Vanivilas Hospital repeatedly failed to convene, and approval got very delayed. Although I waited for as long as possible, and pushed as hard as possible with the hospital management, I eventually had to give up and was unable to include Vanivilas Hospital in my study (Approvals, Appendix U, page 377).

2.6. Building and training the team

The BANGLES team comprised myself, between two and three nutritionists at any one time, and a lab technician (figure: 2.10). They were recruited using advertisements on an employee hunt website and through known networks at my undergraduate alma mater, Mount Carmel College, Bangalore. All were interviewed by myself and my local supervisors.

I trained the team in measuring anthropometry (height and weight), calibrating the weighing scale and stadiometer regularly, approaching and explaining the study to potential participants, checking their eligibility, obtaining consent and administering all the questionnaires. All this included building rapport and ensuring participant engagement through healthy eating counselling and providing refreshments and nutrition pamphlets. All team members were trained to centrifuge, collect serum and plasma samples, store blood samples and liaise with the hospital lab to collect reports.

I organised the equipment and an office to store samples and data, planned the logistics, ran day-to-day clinics, co-ordinated with 15 obstetricians across the 3 hospitals, identified participants from various sections of the antenatal clinic and supervised the team. Weekly meetings were held to assess progress and identify obstacles. The team was applauded for their good work, and given suggestions to cope with difficulties. We discussed new ideas and held weekly journal clubs to maximise motivation and reduce the monotony of data collection. These strategies kept the team in good form.

Figure 2.10: Team 1 (Kaveri M T, Sofiarani, Vinita and me, left to right) and team 2 Krupa, Chaitra, and myself, left to right with Prof Fall)



2.7. Logistics & procedures

2.7.1. Three stages of the study

In stage 1, patients were identified, screened and recruited. Data on peri-conceptual diet, physical activity, socio economic status and health were collected. A blood sample was collected and processed for micronutrient levels. In stage 2 an OGTT was performed and diet was reassessed. In stage 3, birth outcome details were collected (table 2.5). This thesis includes data from stages 1 and 2.

2.7.2. Identifying the patients, screening and recruitment into BANGLES

We recruited consecutive women attending antenatal clinics at both Baptist and Cloudnine hospitals. Identifying pregnant women in early gestation was a challenge. I networked with various hospital staff who worked with a similar gestational window to identify participants: nurses, ultra-sonographers, and counselling centre staff (who need to stamp every patient's lab prescription form). Obstetricians' diaries and outpatient registers were used to compile Expected Delivery Date (EDD) lists. Posters and leaflets in English and regional languages were produced to attract potential participants (figures 2.11, 2.12).

Table 2.5: The three stages of data collection

Round 1 At recruitment (under 17 weeks)	Round 2 (24 – 28 weeks)	Round 3 Post-delivery
<u>Written documentation:</u> Inclusion and exclusion criteria	FFQ of diet in late pregnancy 24-hour recall	Birth outcomes from Hospital records
Participant Information sheet		
Participant Informed consent		
Food Frequency Questionnaire (FFQ) of peri-conceptual diet		
24-hour recall		

Round 1 At recruitment (under 17 weeks)	Round 2 (24 – 28 weeks)	Round 3 Post-delivery
International Physical Activity Questionnaire (IPAQ short)		
Socio-economic status using NFHS 3 Standard of Living Index		
<u>Blood sample:</u>		
Laboratory: Haemoglobin, random plasma glucose	75-gram Oral Glucose Tolerance Test	
Under 17 weeks' blood sample proforma	24 – 28 weeks' blood sample proforma	
Stored: Plasma for estimating folate, B12 and Vitamin D; Serum for estimating ferritin		
Anthropometry:	Anthropometry:	
Current weight, height	Current weight	

Figure 2.11: A leaflet used for explaining participants about BANGLES

MOM-TO-BE ?

Are you between 12–16 weeks? A single baby? Non diabetic? Planning to stay in Bangalore?

This is for you ...

What you will get:

What we need FROM YOU

In the BANGLE study, We want to study the hottest topic today - Nutrition & Lifestyle habits in detail of pregnant women and we want data on your diet, lifestyle, health & home, in detail and will take about 45 minutes and 2 visits from you.

BANGLES
Bangalore Nutrition
Gestational diabetes
LiFEstyle Study

Who are we

MRC Lifecourse Epidemiology Unit, Southampton is a leader in the area of maternal nutrition research and has presence in India, since 20 years and has done classic studies like the Mysore Parthenon Study, Pune maternal Nutrition Study etc. In this study we are working with many hospitals and in Cloudnine, we will be working with Dr Prakash Kini and Dr Anuradha S.

For more details, please contact:
Anvesha Mahendra
Clinical Nutritionist
Project Lead—BANGLES
Ph : 9663584502

What Will you Get?

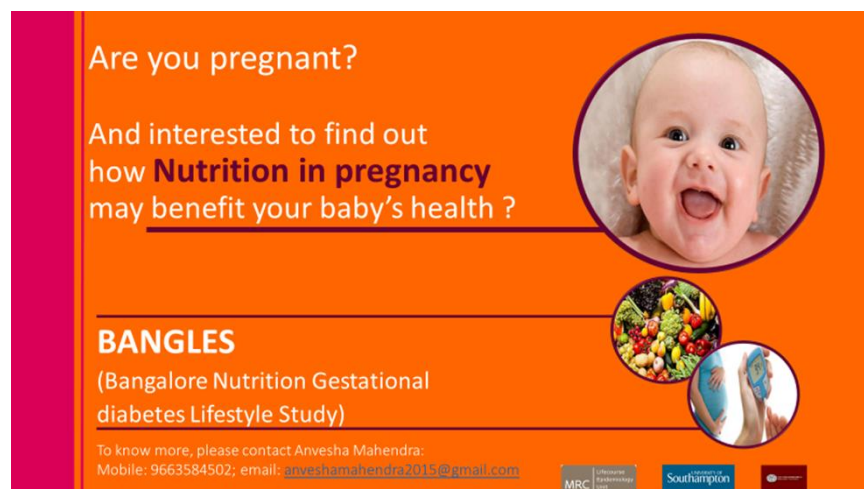
You will be a part of an international study and will uniquely contribute to form lifestyle recommendations for Indian pregnant women. You will receive the following:

VISIT 1 :

- 1.Free tests of Haemoglobin and Random blood sugar
- 2.Good nutrition in pregnancy counseling
- 3.A take home pamphlet on good nutrition in pregnancy
- 4.A refreshment bag

VISIT 2 :

- 1.A free 75 gram Oral Glucose Tolerance Test (OGTT) prescribed by your Obstetrician
- 2.A refreshment bag

Figure 2.12: Poster used to invite participants for BANGLES

2.7.3. Explanation of the study and consent taking

Once a participant was confirmed as satisfying the inclusion criteria (table 2.6, Appendix B, page 287), we gave them an information sheet. We explained the study, including the collection of a blood sample to determine haemoglobin and random plasma glucose (results of which were made available to the participant). Participants were informed that micronutrient levels (ferritin, vitamin D, folate and vitamin B12) would not be available to them, as the samples were stored to be analysed after data collection was completed. The OGTT at 24-28 weeks to diagnose GDM was explained to the patients beforehand to ensure their follow-up. Informed written consent was obtained (participant information sheet & consent form in Appendix C, page 289). After giving their consent, the participant was enrolled into BANGLES and a unique study identity number was allotted.

Table 2.6: Rationale behind the inclusion/ exclusion criteria

Inclusion criteria:	Rationale behind the criteria
Gestational age less than 17 weeks calculated from the Last Menstrual Period (LMP) date.	This was the closest available window to assess peri-conceptional diet. Haemodilution varies according to gestational age, which can affect blood micronutrient levels.
Singleton pregnancy	Multiple or twin pregnancy is an independent risk factor for GDM.
Intent to complete at least 24 weeks of gestation in Bangalore	To ensure complete follow up and obtain the primary outcome of the study.

Exclusion criteria:	Rationale behind the criteria
Absence of known type 1 or 2 diabetes mellitus	To ensure they have not started making dietary changes to control diabetes.
Detected with a positive Human Immuno deficiency Virus (HIV) or Hepatitis blood report before recruitment.	We only had basic training to handle blood samples (using gloves) and did not have facilities to handle serum and plasma separation for HIV or Hepatitis patients.

2.7.4. Questionnaires

Questionnaires were administered by myself and I trained nutritionists to collect information on diet, supplements, socioeconomic status, physical activity and general health (questionnaire tools attached as appendices A to K) (figures 2.13, 2.14 and 2.15).

Figure 2.13: Me collecting data at the Baptist Hospital



Figure 2.14: Nutritionist Unaiza collecting dietary data at the Cloudnine Hospital



Figure 2.15: Nutritionists Krupa and Chaitra collecting data at the Baptist Hospital



2.7.5. Blood sampling & analysis

Recruitment (before 17 weeks): A non-fasting blood sample was collected in an EDTA vacutainer and centrifuged within 30 minutes to collect plasma. Another plain vacutainer was allowed to clot and centrifuged for serum separation. The plasma and serum were distributed into separate aliquots and stored at minus 20-degrees Celsius (figure 2.17). Samples were transferred on dry ice into a minus 80-degree Celsius freezer every 2 months, until analysis; storage time ranged from 2 months to 24 months. Analyses of plasma folate, B12, vitamin D and serum ferritin were performed at the KEM Hospital Diabetes Centre laboratory in Pune, India, which has developed international standardised procedures for these measurements. Folate was measured by a microbiological assay using a chloramphenicol-resistant strain of *L. Casei* (Tamura et al., 1990). Plasma cobalamin (B12) was measured by a microbiological assay using a colistin sulfate-resistant strain of *L. Leichmanii* (Kelleher et al., 1987). Inter and intra-batch CVs for both B12 and folate were <8%. 25-Hydroxy Vitamin D was measured using an enzyme immunoassay kit (IDS Inc., Fountain Hills, ZA85268, USA. Product Code AC-57F1) with a sensitivity of 5 nmol/L and inter and intra-assay CV <8%-9%. Ferritin was measured by ELISA (NovaTec Immundiagnostica GmbH, Germany) with a coefficient of variation (CV) of 9%.

24-28 weeks' gestation: The OGTT was not performed during inter-current illness. The woman was asked to come to the study centre

after an overnight fast for a minimum of 8–10 hours (only water permitted). After a fasting blood sample, she was asked to drink 75-grams of anhydrous glucose dissolved in 300ml of water. Further blood samples for glucose estimation were taken 60 and 120 minutes after consumption of the glucose drink (proforma in Appendix J, page 323). Laboratory glucose measurements used the Hexokinase method. If GDM was diagnosed, the participant was managed by the obstetrician, who decided the course of treatment. We documented the treatment (No treatment, Diet / Diet + Oral Hypoglycaemic Agents (OHA) / Diet + Insulin / Diet + OHA + Insulin) decided by the obstetrician.

Figure 2.16: Blood sampling



2.7.6. Anthropometry

Height and weight were measured at recruitment and at the OGTT follow up (2nd visit). Height was measured to the nearest 0.1 cm using a Harpenden pocket stadiometer (figures 2.18 & 2.19). Weight was measured to the nearest 100 g using an electronic digital weighing scale (Salter, India). The woman's lowest ever (minimum) body weight

Figure 2.17: Steps in blood collection and processing



as an adult and pre-pregnancy weight were recalled by the participant (Appendix D, page 292). It was not possible to measure gestational weight gain because that would have required additional follow up, as weight was not routinely checked before delivery.

Figure 2.18: Measuring height



Figure 2.19: A Standard Operative Procedure guide followed to measure height (Adapted from NICE, 2012)

1. Explain to the participant to stand as tall and straight as possible.
2. Alter hairstyles and remove hair accessories that interfere with height measurement.
3. Ensure the participant's feet should be flat on the base plate of the stadiometer and positioned slightly apart, in line with their hips, to aid balance; put equal pressure on both feet and breathe normally.
4. Their knees should be straight and their buttocks, shoulders should touch the stadiometer. Exceptionally for participants with heavier hips this rule was not followed.
5. Ensure the participant's head is in the "Frankfurt plane" (an imaginary line from the centre of the ear hole to the lower border of the eye socket). The participant should be able to step off the stadiometer without bending their head.

2.7.7. Participant engagement and incentives

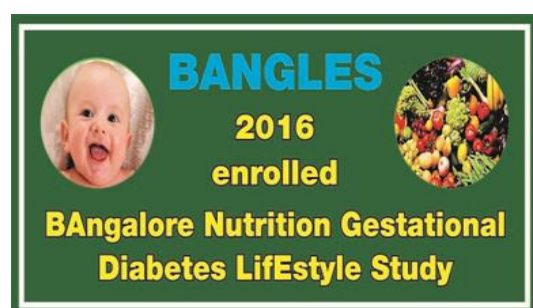
To engage participants and satisfy ethical committee requirements, a 'Good Nutrition During Pregnancy' education pamphlet was provided at the first visit. A 'Good Nutrition during Breastfeeding' education pamphlet was provided during late pregnancy. The pregnancy pamphlet included tips on why good nutrition is important during pregnancy, the role of different

nutrients, the concept of the food pyramid, food hygiene and safety, and healthy recipes (Appendix N, page 334). We do not believe that a single nutrition counselling session during the entire duration of pregnancy affected the women's diets greatly, because dietary and health change behaviour takes time and many sessions (Coulson et al., 2016).

2.7.8. Follow up

We stuck enrolment stickers on antenatal cards after recruitment to track participants, and to ensure obstetricians were informed when participants were recruited (figure 2.20).

Figure: 2.20: Picture of the enrolment sticker



2.8. Data management

2.8.1. Data entry, storage and cleaning

Questionnaires were stored in locked filing cabinets and on password-protected computers. Data were double entered on different computers, using Microsoft Access databases. Two independent programmers from Mysore and Southampton checked the two entries for consistency and plausibility. Discrepancies were checked against the hard copy entry. Cleaned anonymised data were used to prepare analysis files and compute scores for socio economic status using standard NFHS 2 scoring guidelines (NFHS-2, 1998-99) by Ms. Patsy Coakley, senior programmer at the MRC LEU. This dataset was encrypted to protect the identity of participants.

2.8.2. Processing of dietary data

The 224 foods in the FFQ were initially grouped into 21 food groups (table 2.7) representing families of foods that participants and researchers were familiar with. Diet patterns best capture the totality of diet – the combinations and quantities in which foods and nutrients are consumed. I shall use these food groups and diet patterns to study associations of diet with population characteristics and GDM in my results chapters. A synthesis of systematic reviews suggests that a dietary pattern method better captures the relationship between the diet and health outcomes of interest and quality, than single foods and nutrients thereby overcoming the collinearity among single foods and nutrients (Alexandria, 2014). For the dietary pattern analysis, I shall use a different food grouping system (described in chapter 7, details in Appendix R, page 367).

Table 2.7: Classification of 224 food items on the BANGLES FFQ into 21 food groups

Milled cereals & products	Poultry
Whole grain cereals	Meat
Pulse and lentil preparations	Milk and dairy products
Salads and raw vegetables	Coffee
Cooked vegetables	Fried and fast food
Potato containing dishes	Added sugar, SSB and high sugar products
Potato palya	Nutrient enriched beverage supplements
Cooked green leafy vegetables	High salt products
Fresh fruit, dried fruit and fruit juices	Visible fat
Nuts and seeds	
Fish and seafood	
Egg and egg preparations	

2.8.3. Rationale of grouping the foods

The 21 food groups were created based on the nutrient content of food items (table 2.7, see Appendix M, page 328 for constituents of these food groups).

- a. Cereals were divided into whole grain and milled products because fibre influences postprandial glycaemia. Some rice dishes, e.g. egg or

chicken biriyani, were grouped separately, because their protein and heme-iron content differ from cereals alone.

- b. Whole pulses (chickpeas and kidney beans), dals (toor and moong dal), peas, and their preparations, were grouped under Pulse and lentil preparations. Cooked vegetables including roots and tubers (excluding potato), gourds, brinjal (aubergine) and their preparations were grouped together.
- c. Cooked green leafy vegetables had their own section since there is some evidence that they are protective against T2DM. Salad and raw vegetables were grouped separately, because raw and cooked vegetables differ significantly in their nutrient-content and metabolic effects.
- d. Fresh fruit, fresh fruit juices, tender coconut water and unsweetened dried fruit were put into a separate category because they are similar in nutrient content.
- e. Poultry, meat and fish were each grouped separately because they differ in their heme and non-heme iron, fat, protein, retinol and energy-content.
- f. Milk-based beverages (tea, coffee, milk, flavoured milks), curd, paneer, cheese and ice creams were grouped under milk and dairy products.
- g. Fast foods (pizza, burger and Indian fried snacks) were grouped together because they are similar in their energy and fat-content.
- h. Added sugar, sugar products and sugar sweetened beverages (SSB) including sugar added to coffee, packaged fruit juices, aerated drinks, chocolates, sweets, traditional Indian and western sweets were grouped together. A separate group was created for nutrient enriched beverage supplements; although high in sugar, they are enriched with minerals, vitamins and trace elements.
- i. Ghee and butter were grouped separately as visible fat.
- j. Coffee was grouped separately as it has been associated with a lower risk for T2DM (Muley et al., 2012).
- k. Potato palya (a side dish containing only potato) and potato-containing dishes including masala dosa, alu parantha, alu bonda were grouped separately because a higher potato intake has been associated with higher GDM risk (Bao et al., 2016). I chose to keep potato palya and other potato containing dishes as separate groups because they differ

in their oil content and ingredients. 'Other' potato containing dishes include masala dosa, parantha, bonda and chips, which contain much more oil and ingredients such as rice, wheat, and chickpea flour. I wanted to explore whether any associations between potato and GDM were due to potato itself or other ingredients.

2.8.4. Processing of other foods recorded on FFQ

Foods that women reported eating but were not on the FFQ were recorded as 'other foods' in a separate section of the FFQ. Some of these were merged into similar FFQ sections (sample technique in Appendix O, page 336). For example: coconut milk and barley water are healthy, rich in minerals and have negligible sugar. Coconut milk was merged with coconut chutney, and barley water with tender coconut water. Watermelon seeds were clubbed with pumpkin seeds. Dried figs and dates were clubbed with fresh figs and dates. Appam (a popular south Indian pancake made of fermented rice) was grouped with plain dosa. Nutrient enriched supplements (B-Protein, Amway protein powder, Ensure, Protein X, Sim Mom protein powder and pregender were clubbed with Pro PL, which was already on the FFQ.

Some foods required the creation of new categories. Green tea, juices of bramhi, banana-stem, Indian basil, wheat grass, bitter gourd and aloe vera were sufficiently different from any existing FFQ items, and hence was grouped separately as 'herbal drinks'. Avocado stands out from other fruits, being high in monounsaturated fats, calories, B-vitamins and beta carotene, and was grouped separately. Raw greens are different in nutrient composition from usual salad vegetables such as cucumber, tomato, onion and carrot, and were grouped separately. Dry chutney powders (curry leaf, flaxseed, garlic and lentil) were grouped as dry chutney powders.

2.9. Coding of variables

2.9.1. GDM

A binary variable (yes = 1 and no = 0) was created based on OGTT data. The majority of women completed a glucose tolerance test (GTT) with 3 blood glucose values. Despite the obstetricians agreeing to the standard OGTT

protocol, there were 35 women who had a glucose challenge test (GCT) instead, which includes a single blood glucose value 1 hour after consuming a 50-gram glucose drink. Although it is widely known that an OGTT is more reliable, women whose GCT was positive were subsequently managed as cases of GDM. Finally, 677 completed a 75-gram GTT, 35 women completed a 50-gram GCT and 2 women had fasting and postprandial plasma glucose tests. Out of these, 139 women were diagnosed as GDM by OGTT and 18 women were diagnosed as GDM by GCT. In my analysis, all women managed as GDM were included as cases.

2.9.2. Area of residence

Area of residence was coded using the pin codes (post codes) from the Census of India directory for urban and rural Bangalore (Census of India, 2011). 12 women from outside Bangalore were assigned urban and rural codes using pin codes for their states.

2.9.3. Occupations

There is no universally accepted classification for ranking occupations in India. I used the modified Kuppuswamy scale (Mishra & Singh, 2003) as a template for the 'hierarchy' of occupations. Additionally, I referred to the International Standard Classification of Occupations (ISCO-08) devised by the International Labour Organisation, Geneva (ISCO-08, International Labour Office, 2012). This was useful to understand the skills and education required for different jobs. Similar to both these references, I used a hybrid system to classify occupations combining education, occupation and societal status and customised it to my study population. I listed all the occupations recorded and then manually coded them (table 2.8). Income was indicated as a characteristic of occupation but was not used for classification, as income levels fluctuate (Mishra & Singh, 2003).

2.9.4. Education

I used Kuppuswamy's 7-level scale to classify attained education: professional or postgraduate degree, graduate degree, intermediate, high school, middle school, primary school and illiterate (Kuppuswamy, 1981).

Table 2.8: Classification of occupations

Category	Education	Characteristics	Monthly Income*	Occupations included
High-end professionals	Most have received higher education	Leadership, responsibility, executive functions, policy making	>INR 100,000	Chief executive officer, chief operating officer, chief financial officer, company founder, industry head, doctor, university teacher/scientist, lawyer
Mid-level professionals	Graduate education and at least 6 years of experience	Managerial and/or high level skills	>INR 40,000	Mechanical and electrical engineer, systems executive, finance executive, customs officer, army officer, banking/finance associate, manager, systems analyst, medium-sized-business owner,
Highly skilled & technically trained	Education for technical training or vocational courses.		>INR 25,000	School teacher, IT administrator, network engineer, counsellor, information officer, business development executive, purchase executive, travel consultant, marketing executive, promoter, medical representative, qualified nurse (degree), police inspector, CBI, army officer (non-commissioned), translators, interior designer, fashion designer – small scale company and technician (including operation theatre, industry, equipment, anaesthesia and lab).
Skilled	Require basic job-related training and basic education at pre-university and Intermediate level.		>INR 15,000	Cameraman, gram panchayat social worker, school of nursing secretary, customer executive, bible reader in church, bank end job, guest relation executive, guest service assistant, accountant assistant, farm owner, agriculturist, own agriculture, goldsmith or artisan, priest, nurse (diploma). cameraman, gram panchayat, social worker, school of nursing secretary, customer executive, army jawan, traffic constable, police constable, medical shop/pharmacy cashier, billing and salesmen.
Semi-skilled	No formal technical training or education	Need to learn job-related skills	>INR 8000 and above	Choreographer, office admin, private or government clerk, receptionist, pharma dispensers, tailor, florist, beautician, carpenter, furniture maker, fitter or joiner.
Unskilled	Neither education nor training.		>INR 5000 and above	Watchman, peon, domestic servant, rickshaw puller, labourer, coolie, vegetable seller, tea or coffee maker, housekeeping staff, cook and security guard.

Category	Education	Characteristics	Monthly Income*	Occupations included
Not employed				
Homemakers		Includes individuals who were working previously, but had taken a sabbatical temporarily and are economically inactive Includes homemakers, who maybe educationally qualified but don't have a job and are economically inactive. Includes women who have chosen to stay at home to care for family or who are not educated and compelled to stay at home.		
Student/ studying		Includes individuals studying towards a higher degree including undergraduate or masters or doctorate.		

***Income has been indicated as an occupation characteristic observed in BANGLES, but was not used for classifying occupations.**

2.10. An overview of the statistical analysis plan

2.10.1. Exposures, outcome, confounders and mediators

As per my concept diagram, my exposures of interest were peri-conceptual diet and selected blood micronutrient levels in early pregnancy, and the outcome was GDM (figure 2.21, page 94). Diet was represented by the weekly frequency of intake of each of the 21 food groups (page 85), and diet patterns derived using Principal Components Analysis (page 191). GDM was a binary (0/1 variable). For most of my analyses, all women who were diagnosed by their obstetrician as having GDM were counted as cases, whether they were diagnosed by OGTT or GCT. However, I also carried out a separate (sensitivity) analysis limited to women who had an OGTT strictly classified according to WHO 2013 criteria. I looked at the relationship between diet/micronutrients and GDM using logistic regression.

An important challenge for observational epidemiology is confounding. A confounding factor is one that is related to both the exposure and outcome of interest, but is acting separately from or independent of the key causal pathway that the study is trying to test. Because it is related to both, it can create false and misleading associations between them. A hypothetical example could be socio-economic status (SES). Women of higher SES might have a variety of healthier lifestyle characteristics, including high intakes of fresh fruit and vegetables, good levels of physical activity, moderate alcohol intake, avoidance of smoking, better access to health care, less stressful jobs, less toxic/polluted environments, etc. etc. They might also have less diabetes (this is true in the UK but not necessarily everywhere). Let's pretend that GDM is nothing to do with diet, but is caused by smoke exposure. Because women of higher SES have both better diets and smoke less (and thus have less GDM) analysis of an observational study might easily find a statistical relationship between diet and GDM. The best defence against this pitfall is to adjust the analysis for such confounders, and this will reduce ('attenuate') false associations, although 'residual confounding' can still be a problem.

In contrast to a confounder, a mediator is a factor that is related to both the exposure and the outcome, but which is on the causal pathway between the two. An example relevant to my study is adiposity. The causal association between diet and GDM may be mediated by adiposity (e.g. diet leads to greater adiposity, which leads to GDM). I considered BMI (a proxy indicator of adiposity) as a potential mediator in my analyses. The effect of adjusting the analysis for a mediator is the same as adjusting for a confounder – the association between diet and GDM is attenuated (Vanderweele, 2015). The difference is that it is plausible that diet leads to adiposity and that this leads to GDM, whereas it is not plausible that diet leads to smoke exposure. This illustrates the importance in a particular study of carefully selecting confounders and mediators. There are specific advanced statistical methods for testing for mediation, though I did not use these. The use of micronutrient supplements may be a confounder of diet-GDM associations, because women who take supplements may differ in a variety of ways unrelated to nutrition from women who don't use them. However, supplement use is a direct cause of blood micronutrient levels and hence cannot be a confounder of blood micronutrient-GDM associations.

I took two approaches to selecting confounders to adjust for:

- i) A data-driven method, in which all the potential confounders in the concept diagram were tested in univariate models with the exposure and outcome. Factors associated with both the exposure and outcome and which were unlikely to be on the causal pathway between them were considered confounders.
- ii) An *a priori* approach of adjusting for all potential confounders identified in the literature and used by previous studies in investigating diet/blood micronutrient-GDM associations.

Using both approaches, I also created models with and without adjustment for BMI as a potential mediator.

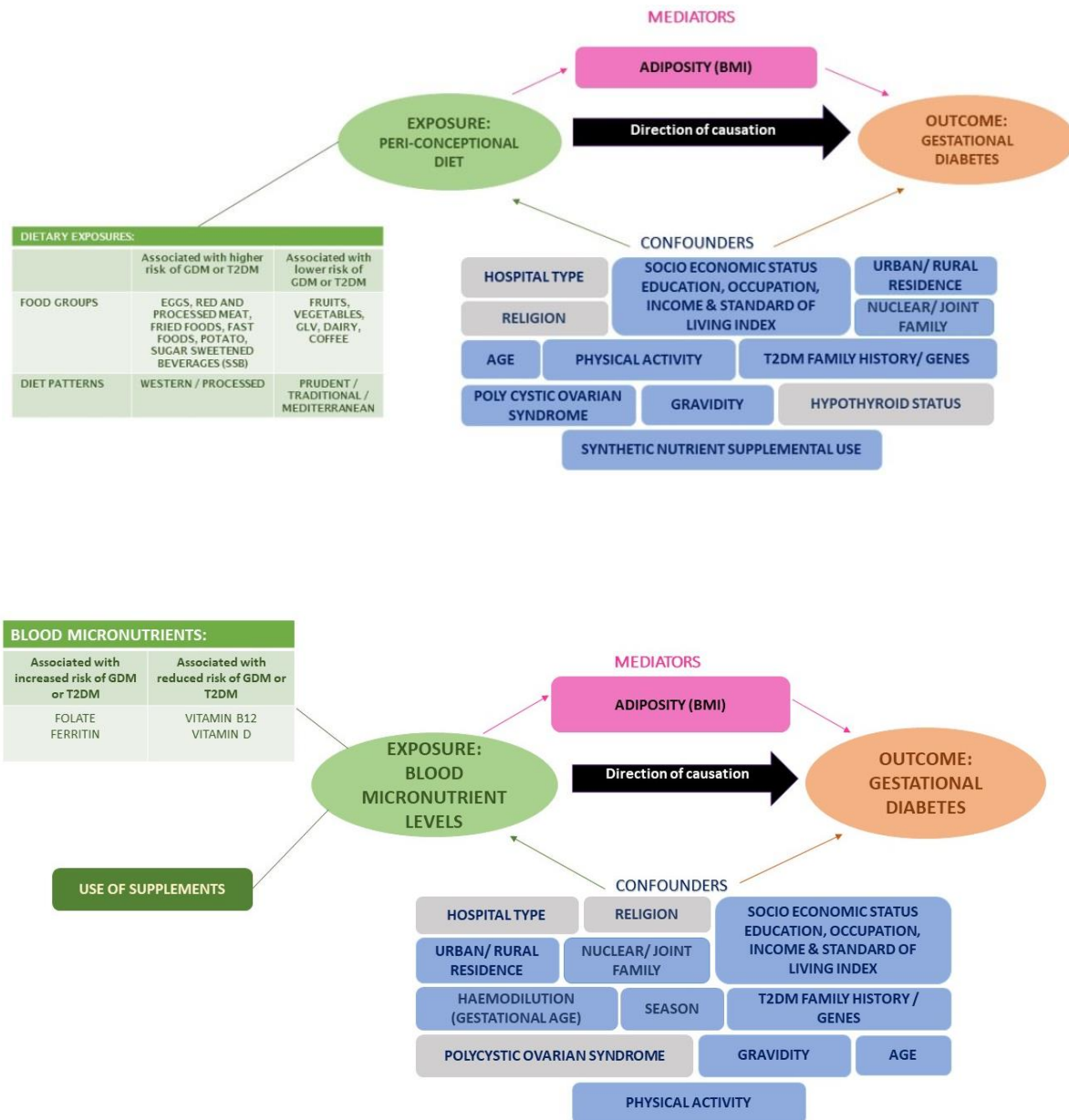
I used the data-driven method to better understand the confounders in my study and their relationship to my exposures and the outcome, in my own setting. In creating the *a priori* models I also explored using Directed Acyclic Graphs (DAGs) from dagitty.net (Textor et al., 2016), an online

platform for drawing and analysing causal diagrams. These were similar to my apriori models.

2.10.2. Statistical significance and multiple testing correction

A p-value of <0.05 is generally considered to indicate that an association is statistically significant. However, when using multiple exposures (eg. 21 food groups) there is an increased chance of type-1 errors (false positives). I addressed this by using significance correction tests, which set more stringent p-value criteria. The Benjamini-Hochberg correction test was used for testing inter-related exposures (e.g. food group intakes), for which a p-value cut-off of 0.002 was used (0.05 significance level/21 food groups). The Bonferroni correction was used for unrelated exposures (e.g. diet patterns and supplemental use), for which a p-value cut-off of <0.01 was used (0.05 significance level/5 diet patterns and 5 types of nutrient supplements). I did not use significance correction tests for associations of blood micronutrients with GDM because here I had hypotheses pre-defined from the literature, that vitamin D and vitamin B12 deficiency, and high ferritin or folate levels would be associated with an increased risk of GDM.

Figure 2.21: Concept diagrams exploring causal associations between exposures and outcome



*Population characteristics in blue boxes treated as potential confounders in diet & blood micronutrient-GDM studies

*Additional population characteristics in grey boxes treated as potential confounders in BANGLES

2.11. Statistical handling of variables

All analyses were carried out using SPSS version 25. My first step was to check the data for implausible values and outliers by generating histograms for variables such as income, scatterplots for height and weight, and minimum and maximum values for dietary data. Age, BMI and SLI were normally distributed (figures 2.22 - 2.24), while income was right skewed and therefore log-transformed and z-standardised for use in regression models (figures 2.25 & 2.26). Occupation, nutraceutical intake and area of residence variables were coded separately, and merged with the final dataset (described, 2.9, pages 87 - 90).

Figure 2.22: Histogram of the woman's age at recruitment (years)

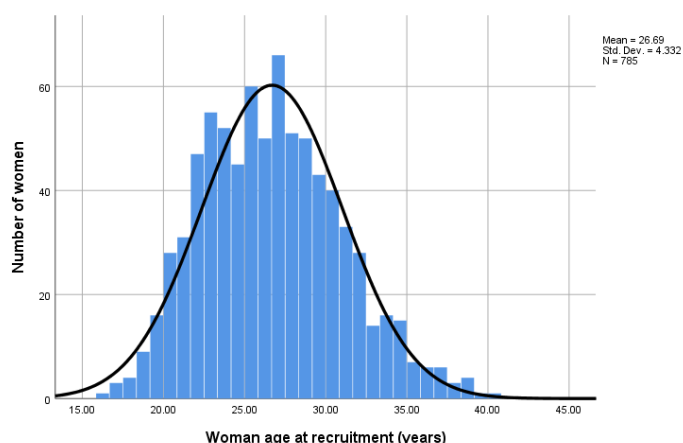


Figure 2.23: Histogram of body mass index variable (Kg/m²)

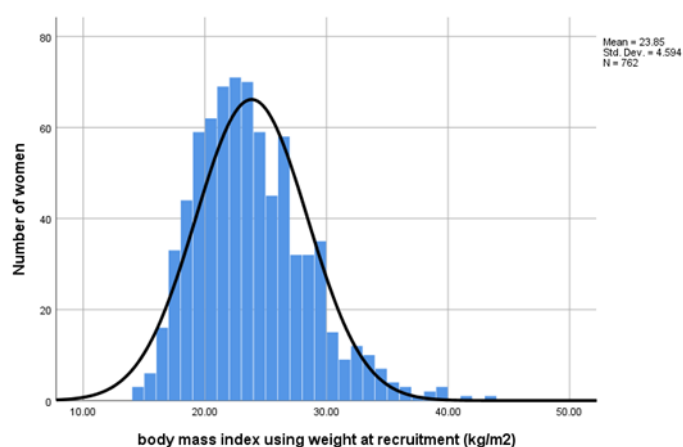


Figure 2.24: Histogram of the total SLI score (score)

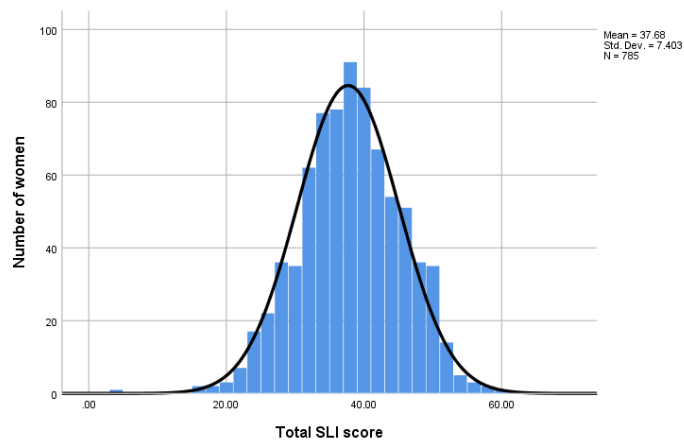


Figure 2.25: Histogram of the total family monthly income (in INR)

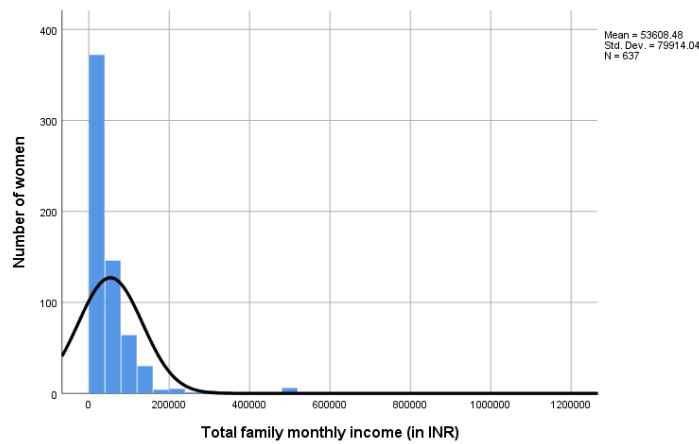
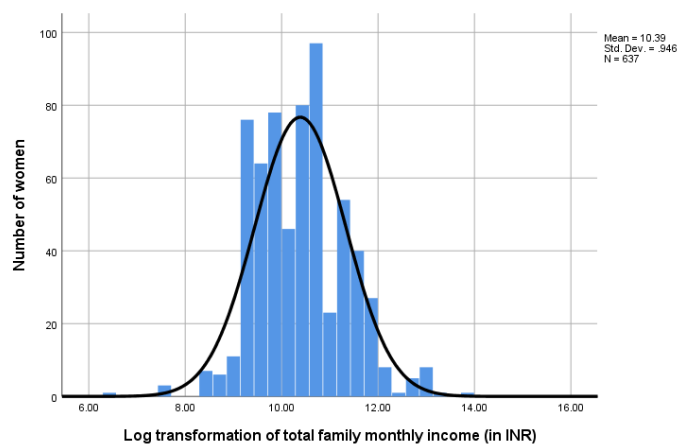


Figure 2.26 Histogram of log-transformed monthly income



2.11.1. Statistical handling of ‘population characteristic’ variables

Computing categorical variables: BMI was categorised based on WHO 1995 criteria (WHO, 1995). SLI and education categories were based on Government of India NFHS 2 guidelines (NFHS-2, 1998-99) and Kuppuswamy SES scales (Kuppuswamy, 1981) respectively. Classification of occupation (described in 2.9.3, page 88). Urban or rural residence was based on the participant’s pin code using the Government of Karnataka directory (Open Government Data Platform India, 2019). Family history of T2DM variable was computed by creating 3 binary categories 1) any first degree relative (i.e. mother, father or siblings); 2) grandparents; 3) no family history. A binary family type variable was computed as follows: nuclear (≤ 3 members); joint (> 3 members). Gravidity was computed as a categorical variable. Zero was considered to mean ‘never pregnant before’ and labelled ‘Primigravida’, while a recorded value of ≥ 1 was considered ‘pregnant before the current pregnancy’ and labelled ‘Multigravida’. Number of miscarriages was handled as follows; Never miscarried or ≥ 1 miscarriage. Various brands and formulations of synthetic nutrients were used by women in the study. Use of tablets of folic acid, vitamin B12, calcium and vitamin D and iron were recorded. Consumption of various other nutrient tablets and enriched beverage supplements recorded on the FFQ and the general health questionnaire were collated to compute a binary variable, indicating using or not using tablets and nutrient enriched beverage supplements. Some continuous variables were categorised for tabulations either into easily interpretable groups or using standard cut points (eg: income, no of rooms in house etc.). Season of blood collection was coded as: winter (January & February), summer (March to May), monsoon (June to September) and spring (October to December).

Physical activity data: IPAQ data was processed as follows:

Step 1) All time measures (vigorous, moderate and low physical activity and screen time were converted from hours to minutes.

Step 2) MET values (the unit energy cost of an activity) were calculated using these formulae in the WHO IPAQ short guidelines (IPAQ group, 2005).

*Walking MET-minutes/week = 3.3 * walking minutes*walking days*

Moderate MET-minutes/week = 4.0 * moderate-intensity activity minutes * moderate days

Vigorous MET-minutes/week = 8.0 * vigorous-intensity activity minutes * vigorous-intensity days

Total physical activity MET-minutes/week = sum of Walking + Moderate + Vigorous MET minutes/week scores.

Step 3) I created physical activity scores of low, medium and high based on the WHO IPAQ short guidelines:

Category 1 Low

Those individuals who do not meet criteria for Categories 2 or 3 are considered to have a 'low' physical activity level.

Category 2 Moderate

a) 3 or more days of vigorous-intensity activity of at least 20 minutes per day.

OR

b) 5 or more days of moderate-intensity activity and/or walking of at least 30 minutes per day.

OR

c) 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum Total physical activity of at least 600 MET-minutes/week.

Category 3 High

a) vigorous-intensity activity on at least 3 days achieving a minimum Total physical activity of at least 1500 MET-minutes/week.

OR

b) 7 or more days of any combination of walking, moderate-intensity or vigorous-intensity activities achieving a minimum Total physical activity of at least 3000 MET-minutes/week.

Step 4) I created a categorical variable for the three levels of physical activity.

The predictor variables of interest included hospital type, religion, income, SLI, participant's education level, area of residence (urban vs. rural), family type (nuclear vs. joint), age, BMI, physical activity, family history of T2DM, presence or absence of PCOS and thyroid problems and gravidity.

Age, SLI and BMI were normally distributed variables and were used as untransformed, continuous variables in the regression models (figures 2.22, 2.23 & 2.24). Income was used as a log transformed, z-standardised variable (figures 2.25 & 2.26). All the others were categorised.

2.11.2. Statistical handling of dietary data

Transformation of food group variables: Most of the food group variables were not normally distributed and therefore required transformation and z-score standardisation before regression analysis. Where transformation did not achieve approximately normal distributions, binary and categorical variables were created.

The milled cereals & products food group variable was normally distributed (figure 2.27) and hence did not require transformation. For all the other food group variables, a sequence of transformations (log, log x+1, square and square root) was followed, and the transformed variable was selected based on 3 criteria: looking at the histogram, computing skewness (closest to zero) and, computing the ratio of standard error and skewness (less than 2). For example, for the pulse & lentil preparations food group variable (figures 2.28 to 2.31), the log and log(x+1) transformation (figure 2.30) looked the most appropriate. Log was not feasible as it excluded 12 women who reported zero consumption (the log of zero is not a finite number). Hence I selected log(x+1) which included the whole sample and had the best skewness and standard error characteristics (table 2.9). Once I had chosen the least skewed transformation for every food group variable, I created z-scores so that all continuously distributed food group variables were in the same units, to make interpretation easier across different food groups, when comparing effects.

Figure 2.27: Histogram of the milled cereals & products

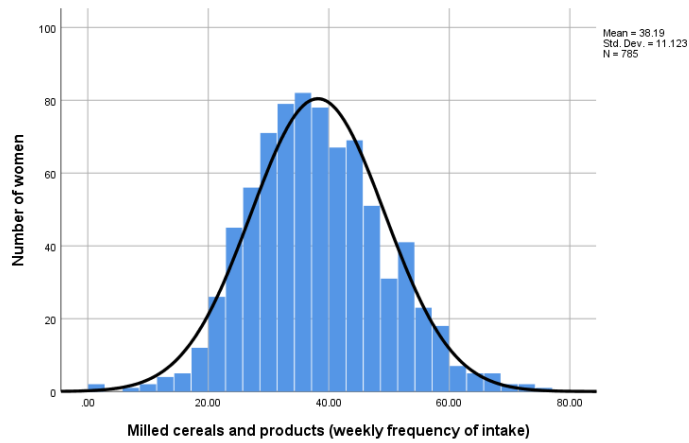


Figure 2.28: Histogram of the pulse & lentil preparations before transformation

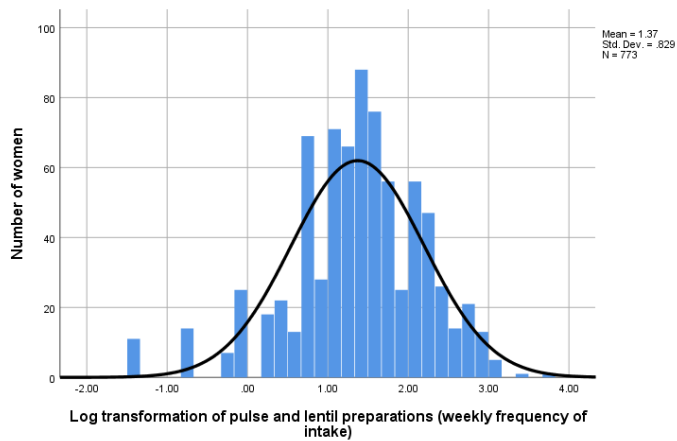


Figure 2.29: Histogram of the log transformation of pulse & lentil preparations

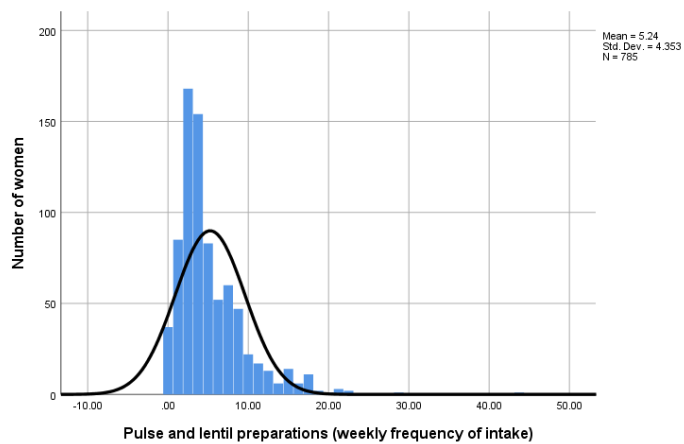


Figure 2.30: Histogram of the log (x+1) transformation of pulse & lentil preparations

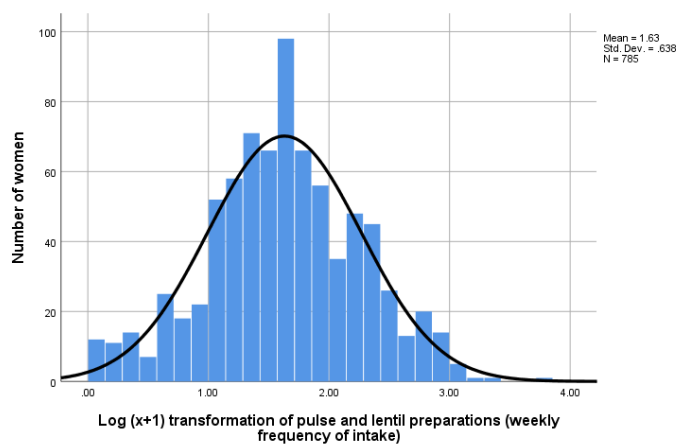


Figure 2.31: Histogram of the square root transformation of pulse & lentil preparations

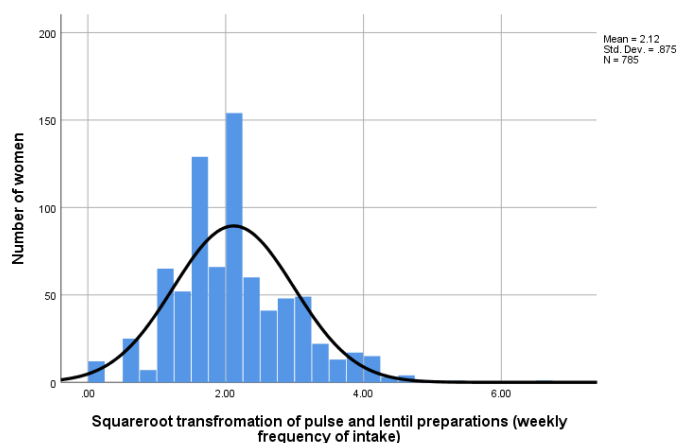


Table 2.9: Skewness and ratio of skewness to standard error for the pulse & lentil preparations variable and its transformed variants

	N	Skewness	Std. Error	Ratio of skewness and SE
Untransformed	785	2.307	0.087	26.51
Log transformation	773	- 0.600	0.088	- 6.81
Log (x+ 1) transformation	785	- 0.050	0.087	- 0.57
Square root transformation	785	0.594	0.087	6.82

Binary & categorical food group variables: Food group variables that were so skewed that transformation was not possible were used as binary and categorical variables. Categories were created with approximately equal numbers of women. For example, the nutrient enriched beverage supplements variable, where intake was low overall, was best used as a binary variable – with either ‘none’ or ‘yes’ categories (figure 2.32). Similarly, where it was important to study the nutritional difference between more than 2 groups, more categories were created. For example, for visible fat - more than 50% consumed this less than once a week, about 25% between 1 and 4 times a week and another 25% more than 4 times a week. Categories of less than once a month and less than once a week were combined because, they may not be very different nutritionally or calorie-wise from each other (figure 2.33). Each type of transformation and categorisation that was followed for all the 21 food group variables have been listed in table 2.10.

Figure 2.32: Histogram cut-points for categories of nutrient enriched beverage supplements

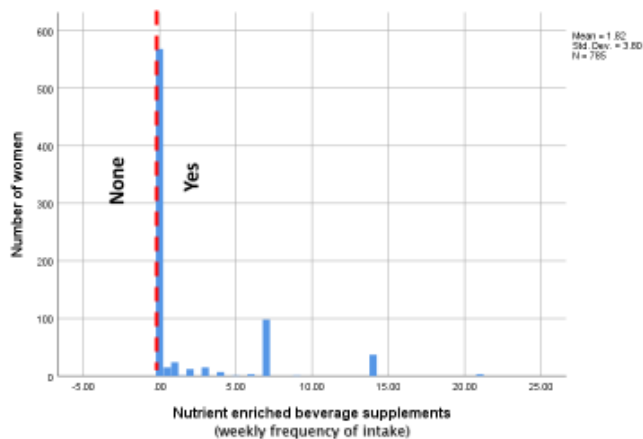


Figure 2.33: Histogram cut-points for categories of visible fats

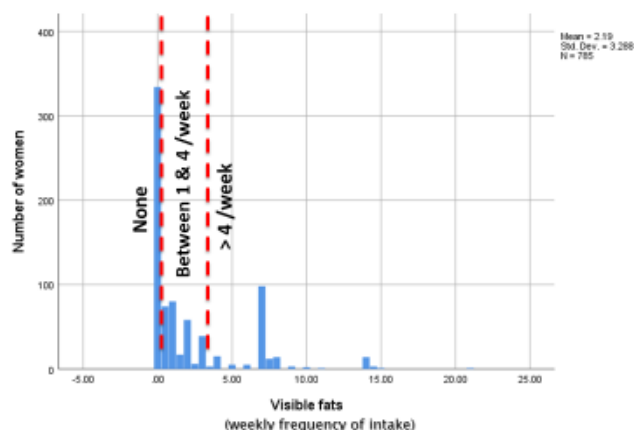


Table 2.10: Transformations used for food group variables

Food group variable	Type of variable	Groups within each variable
Milled cereals & products	Normally distributed (no transformation required)	units = SD
Wholegrain cereals	Binary	Binary variable, 0 = none and 1 = any
Pulse & lentil preparations	Log(x+1)	units = SD
Salads & raw vegetables	Log(x+1)	units = SD
Cooked vegetables	Log(x+1)	units = SD
Potato containing dishes	Binary	Binary variable, 0 = low (≤ 1 / week) and 1 = high (> 1 / week)
Potato palya	Binary	Binary variable, 0 = low (< 1 / week) and high ($1 = \geq 1$ / week)
Cooked green leafy vegetables	Square root	units = SD
Fresh fruit, dried fruit & fruit juices	Square root	units = SD
Fish & seafood	Categorical	3 categories variable, 0 = none, 1 = low (< 1 / week) and 2 = high ($\geq 1 - 3$ / week)
Egg & egg preparations	Categorical	3 categories variable, 0 = low (≤ 1 / week), 1 = medium ($> 1 - 3$ / week) and 2 = high (> 3 / week)
Poultry	Categorical	4 categories variable, 0 = none, 1 = low (≤ 1 / week), 2 = medium ($> 1 - 2$ / week) and 3 = high (> 2 / week)
Meat	Categorical	3 categories variable, 0 = none, 1 = low (< 1 / week), 2 = medium (≥ 1 / week)
Nuts & seeds	Log(x+1)	units = SD.
Milk & dairy products	Square root	units = SD.
Coffee	Binary	Binary variable, 0 = one, 1 = any
Fried & fast food	Square root	units = SD.
Added sugar, SSB & high sugar products	Square root	units = SD
Nutrient enriched beverage supplements	Binary	Binary variable, 0 = none and 1 = any
High salt products	Categorical	4 categories variable, 0 = none, 1 = low (≤ 1 / week), 2 = medium ($> 1 - 3$ / week) and 4 = high (> 3 / week)
Visible fat	Categorical	3 categories variable, 0 = low (< 1 / week), 1 = medium ($\geq 1 - 4$ / week) and 2 = high (> 4 / week)

2.11.3. Methods used for dietary pattern analysis

Diet patterns cannot be measured directly and can be studied using statistical methods such as Principal Component Analysis (PCA), factor analysis, cluster analysis and dietary indices. PCA, factor and cluster analysis are data-driven techniques. Here diet patterns are derived

empirically using calculations and not defined *a priori*, but rather interpreted *a posteriori* (Newby & Tucker, 2004a). Hence this approach is not limited by up-to-date agreement of what describes a healthy diet (Dunteman, 1989). Dietary indices are based on *a priori* concepts of model diet patterns from existing dietary guidelines used by national governments or international agencies (Dunteman, 1989). PCA and factor analysis are quite similar in the principle that both reduce a large number of input variables to a smaller number of independent variables, that explain maximum variability within the sample (Jolliffe & Morgan, 1992). However, the output of factor analysis is a mathematical model that calculates factors based on some assumptions, while PCA looks for linear components within the data, and assesses the degree to which each variable contributes to each component or diet pattern derived (Newby et al., 2004b). PCA can be used to identify foods and food groups that are consumed together as part of a dietary pattern (Newby & Tucker, 2004a). For example, the Southampton Women's survey identified a prudent diet pattern, characterised by high intakes of fruits, vegetables, wholemeal bread, rice and pasta, yoghurt and breakfast cereals (Crozier et al., 2006).

Reasons for choosing PCA over other methods: I chose PCA because, it derives continuous scores for each woman, from which we can get information on the extent of adherence to a diet pattern, which is lost in cluster analysis which derives categorical variables (Newby & Tucker, 2004a). There are no dietary indices developed for adults or reproductive-aged women, that are available in India based on the Indian dietary guidelines and hence could not be used. The dietary guidelines available in India (Dietary Guidelines for Indians, 2010). were initially nutrient (especially calorie) based, and were developed with an objective of tackling the needs of under-nourished populations (Krishnaswamy, 2008), whereas more recently we have a dual burden of underweight and obesity. Now it is increasingly being recognised that there is a need to move from a nutrient-based to a food-based approach (Ritchie et al., 2018). Also the current Indian dietary guidelines are very brief and recommend 'adequate' consumption of grains and pulses, 'plenty' of fruits and vegetables, 'moderate' intake of oils, fats, salt and beverages

and 'low' intake of processed foods (Dietary Guidelines for Indians, 2011). There are knowledge gaps as to what these terms mean at a population level (Ritchie et al., 2018). In the future, I do plan to undertake work on developing diet indices for reproductive-aged women by building it on my work of diet patterns in BANGLE study. The PCA in this thesis was envisioned to be exploratory which may be useful for updating the current Indian dietary guidelines.

2.11.4. Statistical handling of blood micronutrient variables

Blood micronutrient levels were analysed for a subset of 304, due to budget limitations. Of these, 152 had developed GDM and 152 were their age and BMI matched controls. I selected cases and controls using a tolerance range of 2 units for age (years) and BMI (kg/m²) in SPSS.

Vitamin B12 and ferritin were not normally distributed, and were therefore log transformed, and z-standardised scores (SD) were used in regression models (figures 2.34 to 2.37). Folate and vitamin D were highly skewed and hence were used as categorical variables (figures 2.38 and 2.39). Additionally, I used clinical cut-offs available for adults to create categorical variables for all four micronutrients to see how many women were sufficient and deficient.

Many women in the study were using synthetic micronutrient tablets at the time of recruitment. Binary variables indicating using or not using tablets containing folate, vitamin B12, vitamin D and iron were computed.

To study associations between the exposure and population characteristics, I used continuous log transformed z-scores for vitamin B12 and ferritin, and categorical variables for folate and vitamin D. However, to study associations between blood micronutrient and GDM, I used both the continuous and categorical variables for ferritin. The categories and cut off levels for all blood micronutrient variables are summarised in table 2.11, page 108.

Figure 2.34: Histogram of the untransformed plasma B12 level variable

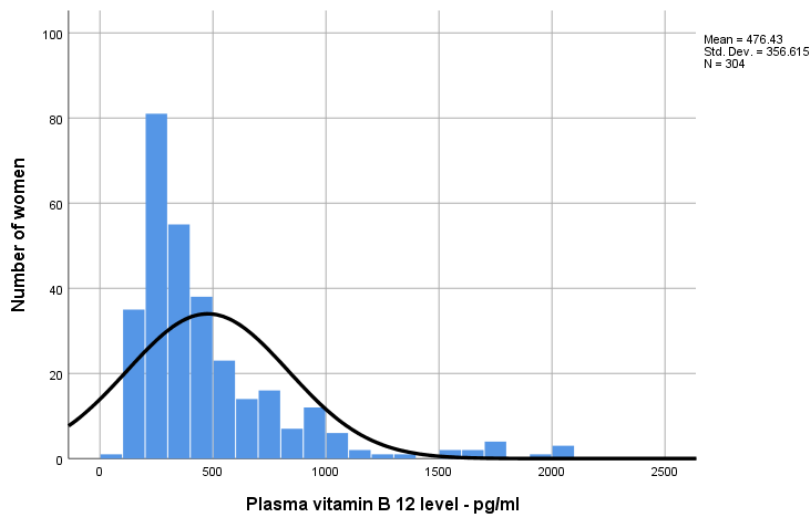


Figure 2.35: Histogram of the log-transformed plasma B12 level variable

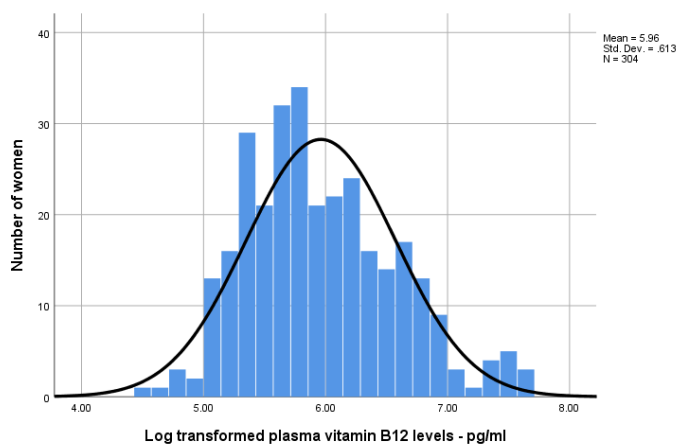


Figure 2.36: Histogram of the untransformed serum ferritin level variable

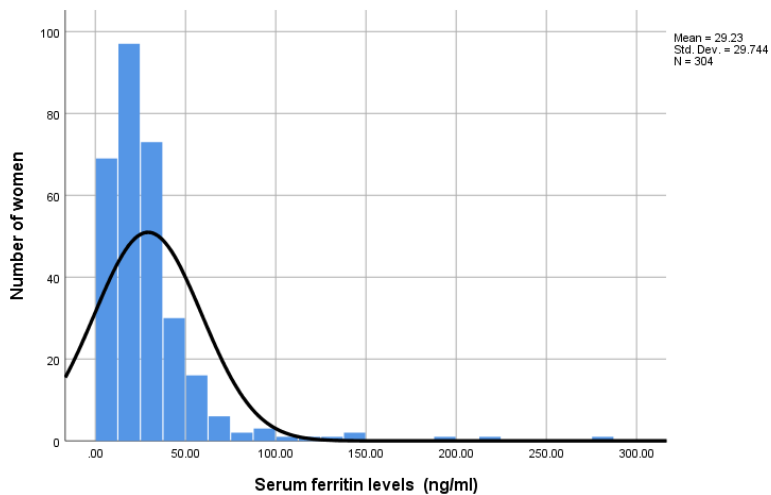


Figure 2.37: Histogram of the log-transformed serum ferritin level variable

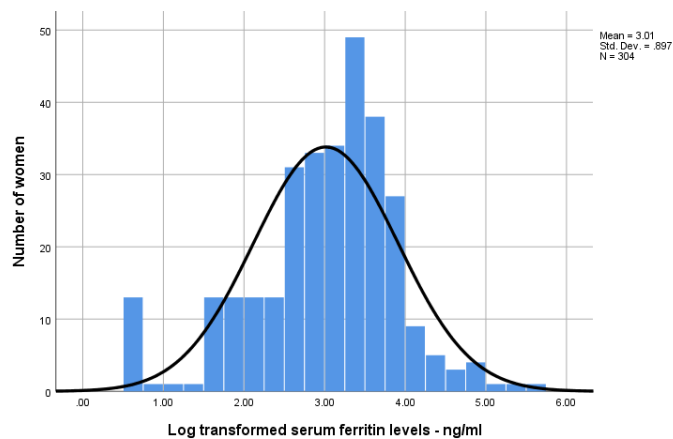


Figure 2.38: Histogram of the plasma folate variable showing the 3 categories created using clinical cut-offs

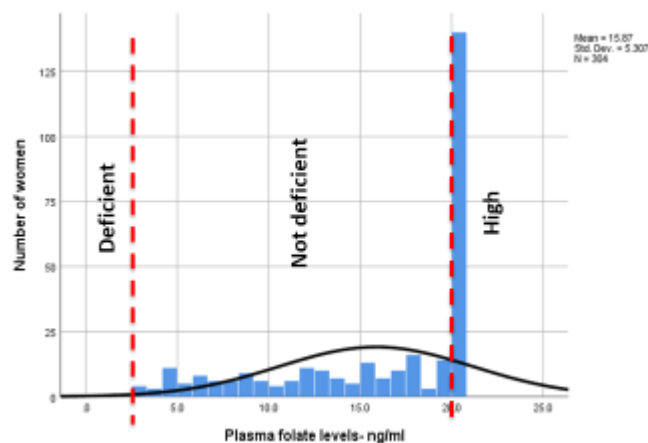


Figure 2.39: Histogram of the plasma vitamin D variable showing the 2 categories created using clinical cut-offs

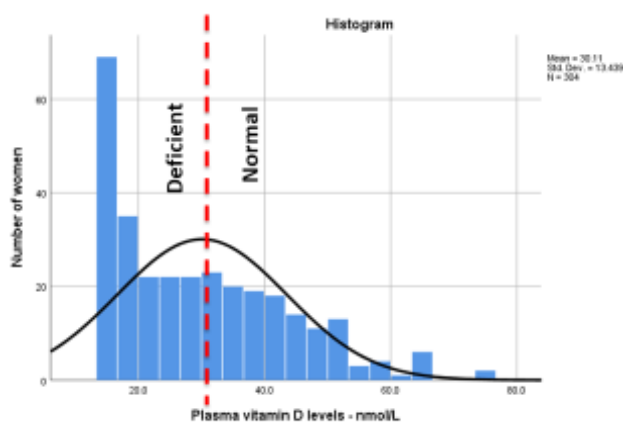


Table 2.11: Transformations and cut-offs used for blood micronutrient variables in regression analysis (n=304)

Food group variable	Type of variable	Groups within each variable	Clinical cut-off values (units)*
Plasma vitamin B12	Continuous (Log, Z-standardised)	units = SD	-
	Categorical	Binary variable, 0 = deficiency, 1 = normal.	Severe deficiency: <136 pg/ ml Deficiency: <203 pg/ml Normal: >203 pg/ml no 'high' defined to date
Serum Ferritin	Continuous (Log, Z-standardised)	units = SD	-
	Categorical	4 categories variable, 0 = low, 1 = borderline, 2 = normal and 3 = high.	Deficiency: ≤15 ng/ ml Borderline: 16 – 40 ng/ml Normal: 41 – 400 ng/ml High: >400 ng/ ml
Plasma folate	Categorical	3 categories variable, 0 = deficient, 1 = normal and 2 = high.	Deficiency: <3 ng/ml Not deficient: ≥3-20 ng/ml High: >20 ng/ml
Plasma vitamin D	Categorical	Binary variable, 0 = deficient, 1=normal	Deficiency: <28 nmol/l Normal: >28 nmol/l *no 'high' defined to date

*ng/ml = nanograms-per-millilitres; pg/ml = picograms-per-millilitres; nmol/l = nanomoles-per-litre.

2.12. Timeline of my PhD

Ethics applications, formulating the study design and questionnaires, establishing protocols, developing training manuals and purchase of supplies, initial staff appointments and training were carried out between February 2016 and June 2016. Additional staff were recruited and trained in Oct to Nov 2016 and July to Aug 2017. Data collection took place during June 2016 to June 2018. I visited the UK once in my first year for coursework, attending an epidemiology course, renewing my fellowship and submitting year one reports. I stayed in the UK for 6

months in year two, finishing my transfer thesis, learning data cleaning and analysis, attending conferences, presenting my initial work and renewing my Schlumberger Foundation fellowship for the final year. I also developed analysis strategies based on the first 300 women recruited. I returned to India for 6 months and completed the data collection, completed data entry, cleaning and coding, carried out age BMI matched case-control analysis for blood samples and transferred samples to Pune for micronutrient analysis. I stayed in the UK from Oct 2018 until submission for data analysis of the full-dataset and thesis writing (figure: 2.40, page 110).

Figure 2.40: Gantt chart showing BANGLES timeline

Tasks	2016				2017				2018				2019			
	JAN-MAR	APR-JUN	JUL-SEP	OCT-DEC	JAN-MAR	APR-JUN	JUL-SEP	OCT-DEC	JAN-MAR	APR-JUN	JUL-SEP	OCT-DEC	JAN-MAR	APR-JUN	JUL-SEP	OCT-DEC
Study design																
Ethics Permissions																
Training of staff																
Recruitment																
Follow-up/OGTTs																
Data entry																
UK visits																
Data cleaning																
Transfer viva																
Sub-set data analysis																
Micronutrient analysis																
Full data analysis																

Chapter 3

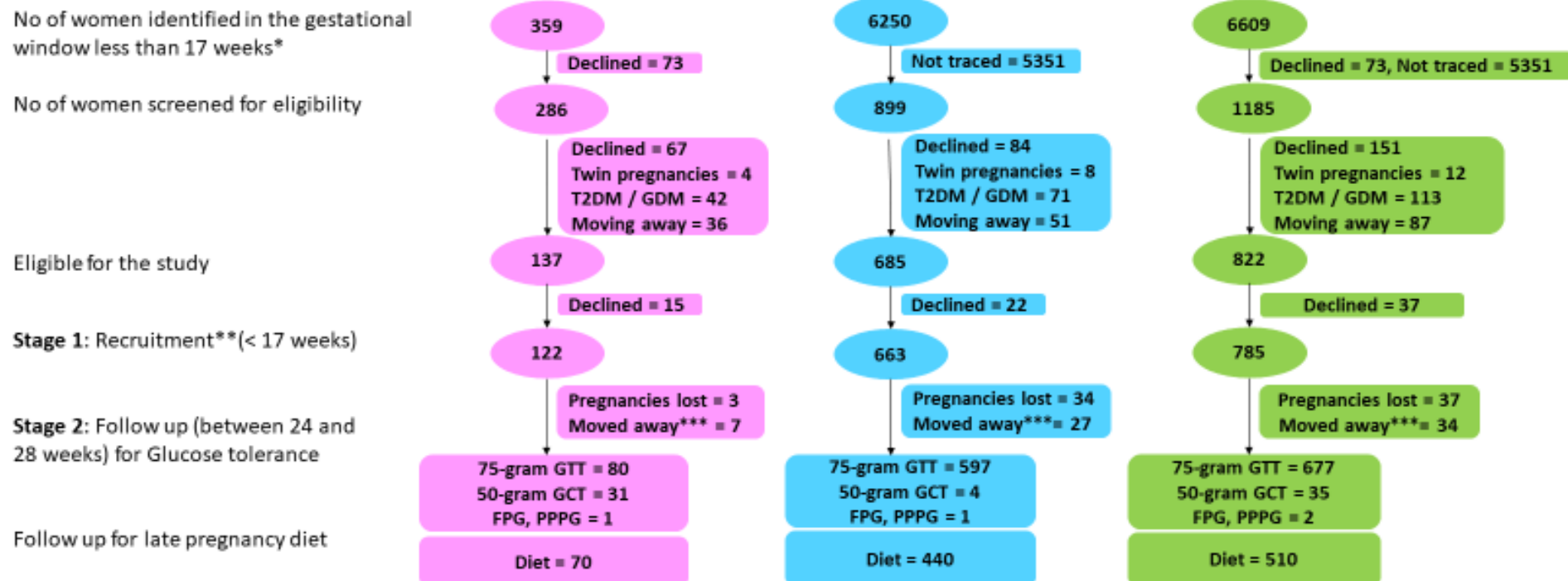
Description of the study population

3.1. Participant flow chart at Cloudnine and Baptist hospitals

Figure 3.1 shows the participant flow at each hospital separately and combined. At Cloudnine 286 women were screened and 137 matched inclusion criteria. Of these 122 women were recruited, of whom 112 women attended visit 2. Of these, 80 underwent a 75-gram Glucose Tolerance Test (GTT), 31 underwent a 50-gram Glucose Challenge Test (GCT) and 1 had fasting plasma glucose (FPG) and 2-hour postprandial plasma glucose (PPPG) tests. We collected dietary data from 70 women at visit 2.

At Baptist, 899 women were screened and 685 matched inclusion criteria with 663 recruited into the study. Of these, 602 attended for visit 2 and 597 women underwent a 75-gram GTT, 4 underwent a Glucose Challenge Test (GCT) and 1 had fasting plasma glucose (FPG) and 2-hour postprandial plasma glucose (PPPG) tests. We collected dietary data from 440 women at visit 2. It was not possible for all women to undergo a 75-gram GTT as planned. Some who had time constraints or lived far away found the test challenging because it required an overnight fast and attending the hospital for a blood sample before 9 am. The Cloudnine policy was to do a 50 gram GCT because it is common obstetric practice in India to do a quick 50-gram GCT for pregnant women, who are rapidly gaining weight or show an abnormal increase in their amniotic fluid.

In total, 785 women were recruited and 677 women underwent a 75-gram GTT, 35 women underwent 50 gram GCT and 2 women got their fasting plasma glucose (FPG) and 2-hour postprandial plasma glucose (PPPG) test done. We collected dietary data from 510 women at visit 2.

Figure 3.1: BANGLES participant flow charts at **Cloudnine** and **Baptist** hospitals, and both **combined**

*The screening procedure was different in Cloudnine and Baptist hospitals. In Cloudnine antenatal women visiting only 1 consultant were screened. In Baptist all antenatal women visiting 12 obstetricians were screened; ** Recruitment included data on diet, general health, socio economic status, physical activity and blood samples; *** Moved away means participants dropped out due to moving to their native place for delivery before 6 months and a change of hospital; GTT = Glucose Tolerance Test; GCT = Glucose Challenge Test; FPG = fasting plasma glucose; PPPG = postprandial plasma glucose

3.2. Differences between Cloudnine and Baptist hospitals in health, religion, socio economic status, area of residence and family.

Statistical handling of variables has been described on page 95. Mean and standard deviation (SD) were computed for normally distributed continuous variables. Median and interquartile ranges (IQR) were calculated for not normally distributed variables. Frequencies and percentages were calculated for categorical variables.

Table 3.1 presents participant health indicators. Women at Baptist were on average 3 years younger than those at Cloudnine. In Cloudnine hospital there were no women younger than 22 years, two thirds were between 26 and 33.9 years, and 15.6% were over 34 years. In Baptist, 16.3% of women were younger than 22 years, about 60% were between 22 and 29.9 years, 13.3% between 30 and 33.9 years and 4.2% over 34 years. The median weight of women in Baptist was 6.3 kg lower. There was not much difference in mean height. The mean BMI was lower in Baptist compared to Cloudnine hospital (23.6 vs. 25.0 kg/m²). Fewer were underweight in Cloudnine compared with Baptist (2 vs. 12%). More than half of the women in both the hospitals were in the normal BMI category. The majority were primi-gravid, three quarters had never had a miscarriage before the current pregnancy, and a large majority conceived naturally without medical intervention, in both the hospitals. Twice as many Cloudnine participants had a T2DM family history and the number with a history of PCOS or thyroid problems was also greater in Cloudnine.

Table 3.1: Health indicators of the participants (n=785*)

Health Indicators	Cloudnine hospital N = 122	Baptist hospital N = 663	Both hospitals combined N = 785
	N (%)		
Mean (SD) age (years)	29.9 (3.6)	26.0 (4.2)	26.7 (4.3)
Age groups <18 years	0 (0.0)	6 (0.9)	6 (0.8)
18 – 21.9 years	0 (0.0)	108 (16.3)	108 (13.8)
22 – 25.9 years	17 (13.9)	231 (34.8)	248 (31.6)
26 – 29.9 years	48 (39.3)	202 (30.5)	250 (31.8)
30 – 33.9 years	38 (31.1)	88 (13.3)	126 (16.1)
Over 34 years	19 (15.6)	28 (4.2)	47 (6.0)
Median (IQR) early pregnancy weight (Kg)	62.5 (54.4, 69.4)	56.2 (49.1, 65.2)	57.0 (50.0, 66.0)
Mean (SD) height (cm)	158.5 (6.7)	156.6 (5.6)	156.8 (5.8)
Mean (SD) BMI (Kg/m ²)	25.0 (4.0)	23.6 (4.6)	23.8 (4.5)

Health Indicators	Cloudnine hospital N = 122	Baptist hospital N = 663	Both hospitals combined N = 785
	N (%)		
Categories of BMI*			
<18.50 (underweight)	2 (1.7)	78 (12.1)	80 (10.5)
18.5 - 24.9 (normal)	61 (51.3)	351 (54.6)	412 (54.1)
25 - 29.9 (overweight)	46 (38.7)	155 (24.1)	201 (26.4)
>30 (obese)	10 (8.4)	59 (9.2)	69 (9.1)
Gravidity ^a			
Primi-gravid	87 (71.3)	442 (66.7)	529 (67.4)
Multi-gravid	221 (33.3)	35 (28.7)	256 (32.6)
Miscarriages before current pregnancy			
Never	92 (75.4)	493 (74.4)	585 (74.5)
1	19 (15.6)	137 (20.7)	156 (19.9)
>1	11 (9.0)	33 (5.0)	44 (5.6)
Conception type			
Natural	117 (95.9)	653 (98.5)	770 (98.1)
ICSI	2 (1.6)	8 (1.2)	10 (1.3)
IUI	1 (0.8)	0 (0.0)	1 (0.1)
IVF	2 (1.6)	2 (0.3)	4 (0.5)
Family history of T2DM from first degree relatives ^b			
Yes	61 (50.0)	188 (28.4)	249 (31.7)
No	61 (50.0)	475 (71.6)	536 (68.3)
History of severe vomiting ^c			
Yes	6 (4.9)	12 (1.7)	18 (2.2)
No	116 (95.0)	651 (98.1)	757 (96.4)
History of Poly Cystic Ovarian Syndrome (PCOS)*			
Yes	32 (26.2)	51 (7.7)	83 (10.6)
No	90 (73.8)	611 (92.3)	701 (89.4)
History of thyroid problems*			
Yes	39 (32.0)	103 (15.6)	142 (18.1)
No	83 (68.0)	558 (84.4)	641 (81.9)
Oral Contraceptive Tablet (OCT) use in the last year before the current pregnancy			
Yes	8 (6.6)	25 (3.8)	33 (4.2)
No	114 (93.4)	638 (96.2)	752 (95.8)

^a Gravidity refers to number of pregnancies. ^b First degree relatives include father, mother and siblings; ^c refers to hospital admissions, and does not include nausea.
Abbreviations: ICSI – Intra Cytoplasmic Sperm Injection, IUI – Intra Uterine Insemination, IVF – In Vitro Fertilisation.
*23 (3.0%) women declined anthropometry; 1 woman did not know if she had PCOS or not and 2 did not know if they had ever been diagnosed with a thyroid problem.

Table 3.2 describes the religion, education, occupation and income of the population. Three quarters of women were Hindus, in both hospitals. In Cloudnine almost all women were educated to graduate and post graduate level with 2.5% educated to pre-university level. At Baptist 2.5% were educated to the level of middle school and less, more than one quarter were educated to the level of high school and pre-university; and 40% were graduates or postgraduates. In Cloudnine over 25% were high end professionals compared to 5% in Baptist. Homemakers constituted a large group in both hospitals with 45.9% in Cloudnine and 73.6% in Baptist. The median income among Cloudnine

participants was four times that of Baptist. In Cloudnine a large majority had a monthly income of greater than INR 100,000. Close to half of households in Baptist had an income range between INR 10,000 - 30,000. 18.8% either preferred not to disclose their family income or did not know. Most women in both hospitals had high SLI scores.

Table 3.2: Religion, Education, Occupation & Income (n=785*)

SES Indicators	Cloudnine hospital N = 122	Baptist hospital N = 663	Both hospitals combined N = 785
	N (%)		
Religion*			
Hindu	104 (85.2)	503 (75.9)	607 (77.3)
Christian	4 (3.3)	107 (16.1)	111 (14.1)
Muslim	4 (3.3)	43 (6.5)	47 (6.0)
Jain	10 (8.2)	1 (0.2)	11 (1.4)
Participant's education level			
Illiterate	0 (0.0)	6 (0.9)	6 (0.8)
Primary school / literate	0 (0.0)	2 (0.3)	2 (0.3)
Middle school completion	0 (0.0)	9 (1.4)	9 (1.1)
High school	0 (0.0)	100 (15.1)	100 (12.7)
Pre – University and Intermediate ^a	3 (2.5)	134 (20.2)	137 (17.5)
Graduate ^b	49 (40.2)	263 (39.7)	312 (39.7)
Post graduate degree and Professional degree ^c	70 (57.4)	149 (22.5)	219 (27.9)
Participant's husband's education level			
Illiterate	0 (0.0)	6 (0.9)	6 (0.8)
Primary school / literate	0 (0.0)	1 (0.2)	1 (0.1)
Middle school completion	0 (0.0)	8 (1.2)	8 (1.0)
High school	0 (0.0)	102 (15.4)	102 (13.0)
Pre – University and Intermediate ^a	4 (3.3)	144 (21.7)	148 (18.9)
Graduate ^b	33 (27.0)	223 (33.6)	256 (32.6)
Post graduate degree and Professional degree ^c	85 (69.7)	179 (27.0)	264 (33.6)
Participant's current occupation level			
High-level professionals	34 (27.9)	35 (5.3)	69 (8.8)
Mid-level professionals	15 (12.3)	56 (8.4)	71 (9.0)
Highly skilled & technically trained occupations	12 (9.8)	45 (6.8)	57 (7.3)
Skilled occupations	3 (2.5)	15 (2.3)	18 (2.3)
Semi-skilled occupations	1 (0.8)	8 (1.2)	9 (1.1)
Unskilled occupations	0 (0.0)	4 (0.6)	4 (0.5)
Not employed currently	1 (0.8)	12 (1.8)	13 (1.7)
Homemaker	56 (45.9)	488 (73.6)	544 (69.3)
Studying/ Student	34 (27.9)	35 (5.3)	69 (8.8)
Participant's husbands occupation level*			
High-level professionals	23 (18.9)	27 (4.1)	50 (6.4)
Mid-level professionals	83 (68.0)	202 (30.5)	285 (36.3)
Highly skilled & technically trained occupations	11 (9.0)	140 (21.1)	151 (19.2)
Skilled occupations	3 (2.5)	155 (23.4)	158 (20.1)
Semi-skilled occupations	1 (0.8)	105 (15.8)	106 (13.5)
Unskilled occupations	0 (0.0)	11 (1.7)	11 (1.4)
Not employed currently	0 (0.0)	0 (0.0)	0 (0.0)
Homemaker	0 (0.0)	0 (0.0)	0 (0.0)

SES Indicators	Cloudnine hospital N = 122	Baptist hospital N = 663	Both hospitals combined N = 785
	N (%)		
Studying /Student	0 (0.0)	0 (0.0)	0 (0.0)
Total family monthly income (1000 INR) ^d			
Median (IQR)	100 (70,150)	25 (15, 41.3)	30 (15, 60)
Categories of total family monthly income			
Below 10,000.0	0 (0.0)	78 (14.7)	78 (12.2)
Between 10,000 to 30,000	3 (2.8)	257 (48.5)	260 (40.8)
Between 30,000 to 50,000	15 (14.0)	116 (21.9)	131 (20.6)
Between 50,000 to 70,000	12 (11.2)	32 (6.0)	44 (6.9)
Between 70,000 to 100,00	31 (29.0)	34 (6.4)	65 (10.2)
Above 1,00,000	46 (43.0)	13 (2.5)	59 (9.3)
Did not want to disclose/ Don't know	15 (12.2)	133 (20.0)	148 (18.8)
Standard of Living Index (SLI) score			
Mean (SD)	42.6 (5.2)	36.7 (7.3)	37.6 (7.4)
Categorisation of SLI scores ^e			
Low	0 (0.0)	1 (0.2)	1 (0.1)
Medium	0 (0.0)	31 (4.7)	31 (3.9)
High	122 (100.0)	631 (95.2)	753 (95.9)

Education classification based on Kuppuswamy SES scale (Kuppuswamy, 1981).
^a Pre - University = HSC, ITI, PUC, Intermediate D. Ed, Post high-school diploma.
^b Graduate = B. A, B. Sc, B. Com, DME, DHMS, BPNA.
^c Post graduate degree and Professional degree = Professional degree, M. A, M. Sc, M. Com, M.Tech, MBBS, B.E, MSW, Postgraduate Diploma.
^d INR = Indian National Rupees (1 GBP = 90.72) as on 8th May, 2019.
^e SLI categorisation from National Family Health Survey - 2 (NFHS 2, 1998-99).
 *Missing data: religion=9, participant's husband's occupation=14, total family monthly Income=148 (18.8%).

Table 3.3 describes area of residence and household assets. Overall, three-quarters of women were from Urban-Bangalore. Baptist hospital had more women than Cloudnine from rural areas (33.7% vs. 11.5%). All women in Cloudnine had a pucca-type of house and more than 90% in Baptist had pucca-type houses. A large majority (>95%) of women in both hospitals had a separate kitchen. The majority (>95%) used the modern Liquid Petroleum Gas (LPG) cylinders for cooking, with a few women (<5%) in Baptist using electricity, wood, crop residues, biogas, coal, kerosene and gobar gas. 61.9% lived in rented houses, not owned by them. Considerably more women in Baptist owned agricultural land, irrigated land and livestock.

Table 3.3: Area of residence, household & related assets (n=785*)

	Cloudnine hospital N = 122	Baptist hospital N = 663	Both hospitals combined N = 785
	N (%)		
Area (Classification from pin code)*			
Bangalore Urban	108 (88.5)	431 (66.3)	539 (69.8)
Bangalore Rural	14 (11.5)	219 (33.7)	233 (30.2)

	Cloudnine hospital N = 122	Baptist hospital N = 663	Both hospitals combined N = 785
	N (%)		
House type			
Pucca ^a	122 (100.0)	606 (91.4)	728 (92.7)
Semi – pucca ^b	0 (0.0)	55 (8.3)	55 (7.0)
Kaccha ^c	0 (0.0)	2 (0.3)	2 (0.3)
Roof type:			
Pucca ^a	120 (100.0)	609 (91.9)	729 (93.1)
Semi – pucca ^b	0 (0.0)	52 (7.8)	52 (6.6)
Kaccha ^c	0 (0.0)	2 (0.3)	2 (0.3)
Walls type:			
Pucca ^a	120 (100.0)	623 (94.0)	743 (94.9)
Semi – pucca ^b	0 (0.0)	38 (5.7)	38 (4.9)
Kaccha ^c	0 (0.0)	2 (0.3)	2 (0.3)
Floor type			
Pucca ^a	120 (100.0)	620 (93.5)	740 (94.5)
Semi – pucca ^b	0 (0.0)	42 (6.3)	42 (5.4)
Kaccha ^c	0 (0.0)	1 (0.2)	1 (0.1)
No of rooms			
1-2	3 (2.5)	28 (4.2)	31 (3.9)
2-3	10 (8.3)	254 (38.4)	264 (33.7)
3-4	29 (24.0)	245 (37.0)	274 (35.0)
7 +	79 (65.3)	66 (10.0)	214 (27.1)
Separate kitchen			
Yes	122 (100.0)	634 (95.6)	756 (96.3)
No	0 (0.0)	29 (4.4)	29 (3.7)
Fuel for cooking used			
Electricity	12 (1.8)	3 (2.5)	15 (1.9)
Liquid Petroleum Gas (LPG)	639 (96.4)	119 (97.5)	758 (96.6)
Others**	3 (2.5)	28 (4.3)	31 (3.9)
House ownership			
Yes	50 (41.0)	249 (37.6)	299 (38.1)
No	72 (59.0)	414 (62.4)	486 (61.9)
Possession of agricultural land			
Yes	29 (23.8)	254 (38.3)	283 (36.1)
No	93 (76.2)	408 (61.5)	501 (63.8)
Size of agricultural land owned			
Don't own any	101 (82.8)	478 (72.1)	579 (73.8)
1 – 5 acres	12 (9.8)	12 (9.8)	159 (20.3)
6 – 10 acres	4 (3.3)	4 (3.3)	29 (3.7)
>10 acres	5 (4.1)	5 (4.1)	18 (2.3)
Size of irrigated land owned			
Don't own any	104 (85.2)	518 (78.1)	622 (79.2)
1 – 5 acres	11 (9.0)	124 (18.7)	135 (17.2)
6 – 10 acres	3 (2.5)	14 (2.1)	17 (2.2)
>10 acres	4 (3.3)	7 (1.1)	11 (1.4)
Possession of livestock ^d			
Yes	128 (19.3)	8 (6.6)	136 (17.3)
No	535 (80.7)	114 (93.4)	649 (82.7)

Descriptions from NFHS 2, 1998-99 guidelines.

^a Pucca House: walls and roof made from burnt bricks, stones (packed with lime/cement), cement concrete, timber, ekra etc. Roof Material: tiles, galvanised corrugated Iron sheets, asbestos cement sheet, reinforced brick concrete, reinforced cement concrete and timber etc.

^b Semi-Pucca house: fixed walls made of pucca material but roof is made of other materials.

^c Kaccha House: Walls and/or roof made of material other than those mentioned above, e.g. un-burnt bricks, bamboo, mud, grass, reeds, thatch, loosely packed stones etc.

^d Refers to owning animals such as cows, buffaloes, bulls, hens, goats and donkeys.

*Missing data: area of residence =13, no of rooms = 2, agricultural land =1.

	Cloudnine hospital N = 122	Baptist hospital N = 663	Both hospitals combined N = 785
	N (%)		
**Others: wood, crop, biogas, coal/ charcoal, kerosene and gobar gas.			

Table 3.4 describes participants' basic household facilities. Half had piped water as the main drinking water source. At Baptist, piped water, followed by purchased bottled water, were the main sources, whereas in Cloudnine piped water, followed by purchased bottled water and well/bore-well were the household's main sources. Over 98% of houses were electrified, in both the hospitals. Most Cloudnine participants had flush toilets with only 9.8% of women having latrines. In Baptist 68% had flush toilets, followed by 29.9% with latrines/pit toilets.

Table 3.4: Basic household facilities (n=785)

	Cloudnine hospital N = 122	Baptist hospital N = 663	Both hospitals combined N = 785
	N (%)		
Drinking water source			
Piped water	78 (63.9)	325 (49.0)	403 (51.3)
Hand pump	0 (0.0)	30 (4.5)	30 (3.8)
Well	17 (13.9)	14 (2.1)	31 (3.9)
River / stream	0 (0.0)	2 (0.3)	2 (0.3)
Tanker	1 (0.8)	4 (0.6)	5 (0.6)
Other ^a	2 (1.6)	11 (1.7)	13 (1.7)
Lighting source			
Electricity	122 (100.0)	650 (98.0)	772 (98.3)
Kerosene	0 (0.0)	1 (0.2)	1 (0.1)
Gas	0 (0.0)	9 (1.4)	9 (1.1)
Solar	0 (0.0)	3 (0.5)	3 (0.4)
Toilet facility type			
Own flush toilet	109 (89.3)	451 (68.0)	560 (71.3)
Shared flush toilet	1 (0.8)	10 (1.5)	11 (1.4)
Own latrine	12 (9.8)	198 (29.9)	210 (26.8)
Shared latrine	0 (0.0)	2 (0.3)	2 (0.3)
No facility / bush / field	0 (0.0)	2 (0.3)	2 (0.3)

^a Other drinking water source includes the purchased bottled water.

Table 3.5 describes household asset ownership. Major differences were seen between Baptist and Cloudnine hospitals in owning an air conditioner (4.7 vs. 39.3%), refrigerator (72.4 vs. 99.2%), radio (23.7 vs. 45.1%), car (38.5 vs. 84.4%),

landline telephone (11.9% vs. 51.6%), computer (47.2 vs. 92.6%) and internet access at home (40.3 vs. 91.8%).

Table 3.5: Ownership of household assets (n=785)

	Cloudnine hospital N = 122	Baptist hospital N = 663	Both hospitals combined N = 785
	N (%)		
Cot/bed	120 (98.4)	616 (92.9)	736 (93.8)
Mattress	122 (100.0)	623 (94.0)	745 (94.9)
Pressure cooker	122 (100.0)	649 (97.9)	771 (98.2)
Chair	122 (100.0)	632 (95.3)	754 (96.1)
Table	122 (100.0)	559 (84.3)	681 (86.8)
Clock/ watch	122 (100.0)	634 (95.6)	756 (96.3)
Electric fan	122 (100.0)	657 (99.1)	779 (99.2)
Air conditioner	48 (39.3)	31 (4.7)	79 (10.1)
Refrigerator	121 (99.2)	480 (72.4)	601 (76.6)
Washing machine	117 (95.9)	339 (51.1)	456 (58.1)
Sewing machine	38 (31.1)	157 (23.7)	195 (24.8)
Radio / transistor	55 (45.1)	157 (23.7)	212 (27.0)
Television (Black & White)	0 (0.0)	9 (1.4)	9 (1.1)
Television (Colour)	120 (98.4)	620 (93.5)	740 (94.3)
Television (Plasma)	95 (77.9)	370 (55.8)	465 (59.2)
Bicycle	50 (41.0)	254 (38.3)	304 (38.7)
Moped/scooter/motorcycle	99 (81.1)	569 (85.8)	668 (85.1)
Car	103 (84.4)	255 (38.5)	358 (45.6)
Water pump	71 (58.2)	309 (46.6)	380 (48.4)
Bullock cart	2 (1.6)	16 (2.4)	18 (2.3)
Thresher	1 (0.8)	25 (3.8)	26 (3.3)
Tractor	5 (4.1)	45 (6.8)	50 (6.4)
Telephone	63 (51.6)	79 (11.9)	142 (18.1)
Mobile phone	122 (100.0)	662 (99.8)	784 (99.9)
Computer	113 (92.6)	313 (47.2)	426 (54.3)
Internet access at home	112 (91.8)	267 (40.3)	379 (48.3)

Table 3.6 (page 120) presents family type and household size data. There were slightly more women in Cloudnine living in nuclear families. Household size was variable in both hospitals.

Table 3.6: Family type and household size (n=785)

		Cloudnine hospital N = 122	Baptist hospital N = 663	Both hospitals combined N = 785
		N (%)		
Family type	Nuclear	78 (63.9)	351 (52.9)	429 (54.6)
	Joint	44 (36.1)	312 (47.1)	356 (45.4)
Household size	1	0 (0.0)	3 (0.5)	3 (0.4)
	2	37 (30.3)	157 (23.7)	194 (24.7)
	3	15 (12.3)	129 (19.5)	144 (18.3)
	4	30 (24.6)	119 (17.9)	149 (19.0)
	5	16 (13.1)	92 (13.9)	108 (13.8)
	6	7 (5.7)	57 (8.6)	64 (8.2)
	7	6 (4.9)	37 (5.6)	43 (5.5)
	8	4 (3.3)	24 (3.6)	28 (3.6)
	9	2 (1.6)	14 (2.1)	16 (2.0)
	10 plus	5 (4.1)	31 (5.0)	36 (4.6)

3.3. Differences between hospitals in diet, physical activity and use of nutraceutical tablets and supplements.

Table 3.7 presents the baseline frequency and percentage of food group intakes. Most women consumed milled cereals and products daily. A quarter consumed pulse and lentil preparations more than daily. Frequency of intake of cooked vegetables was greater than salads and raw vegetables. Weekly frequencies of intakes of sugar, SSB and dairy products were high, and half of the women consumed fried and fast food more than once a day.

Cloudnine participants consumed more pulse preparations, salads and raw vegetables, nuts and seeds, and visible fat than women at Baptist. Those in Baptist, consumed more cooked green leafy vegetables. Fresh fruit, juice and dried fruit intake was similar in both hospitals with over 90% consuming these more than once daily. In both hospitals a large proportion did not consume animal source foods. More women in Baptist than Cloudnine consumed fish, egg, poultry and meat at least once a week.

Table 3.7: Peri-conceptional frequency of consumption of 21 food-groups per month (n=785)

Food groups	Frequency of intake of food group					
	<1 / month	< 1 / week	1-2 / week	3-5 / week	6-7 times per week	>7 times per week
	N (%)					
Milled cereals & products	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.8)	121 (99.2)
	2 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	661 (99.7)
	2 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.1)	782 (99.6)
Whole grain cereals	18 (14.8)	14 (11.5)	25 (20.5)	20 (16.4)	10 (8.2)	35 (28.7)
	94 (14.2)	76 (11.5)	73 (11.0)	93 (14.0)	97 (14.6)	230 (34.7)
	112 (14.3)	90 (11.5)	98 (12.5)	113 (14.4)	107 (13.4)	265 (33.3)
Pulse and lentil preparations	1 (0.8)	2 (1.6)	12 (9.8)	31 (25.4)	14 (11.5)	62 (50.8)
	11 (1.7)	30 (4.5)	105 (15.8)	318 (48.0)	73 (11.0)	126 (19.0)
	12 (1.5)	32 (4.1)	117 (14.9)	349 (44.5)	87 (11.1)	188 (23.9)
Salads & raw vegetables	10 (8.2)	8 (6.6)	18 (14.8)	33 (27.0)	13 (10.7)	40 (32.8)
	52 (7.8)	51 (7.7)	169 (25.5)	209 (31.5)	74 (11.2)	108 (16.3)
	62 (7.9)	59 (7.5)	187 (23.8)	242 (30.8)	87 (11.1)	148 (18.9)
Cooked vegetables	1 (0.8)	0 (0.0)	1 (0.8)	15 (12.3)	17 (13.9)	88 (72.1)
	4 (0.6)	2 (0.3)	10 (1.5)	95 (14.3)	107 (16.1)	445 (67.1)
	5 (0.6)	2 (0.3)	11 (1.4)	110 (14)	124 (15.8)	533 (67.9)
Potato containing dishes	5 (4.1)	17 (13.9)	37 (30.3)	48 (39.3)	10 (8.2)	5 (4.1)
	33 (5.0)	70 (10.6)	225 (33.9)	250 (37.7)	37 (5.6)	48 (7.2)
	38 (4.8)	87 (11.1)	262 (33.4)	298 (38.0)	47 (6.0)	53 (6.8)
Potato palya	34 (27.9)	37 (30.3)	41 (33.6)	6 (4.9)	4 (3.3)	0 (0.0)
	135 (20.4)	20 (30.3)	290 (43.7)	29 (4.4)	8 (1.2)	0 (0.0)
	169 (21.5)	238(30.3)	331 (42.2)	35 (4.5)	12 (1.5)	0 (0.0)
Cooked green leafy vegetables	3 (2.5)	12 (9.8)	39 (32.0)	54 (44.3)	7 (5.7)	7 (5.7)
	17 (2.6)	26 (3.9)	138 (20.8)	362 (54.6)	81 (12.2)	39 (5.9)
	20 (2.5)	38 (4.8)	177 (22.5)	416 (53.0)	88 (11.2)	46 (5.9)
Fresh fruit, dried fruit and fruit juices	0 (0.0)	1 (0.8)	0 (0.0)	4 (3.3)	4 (3.3)	113 (92.6)
	1 (0.2)	0 (0.0)	7 (1.1)	15 (2.3)	17 (2.6)	623 (94.0)
	1 (0.1)	1 (0.1)	7 (0.9)	19 (2.4)	21 (2.7)	736 (93.8)
Fish & seafood	85 (69.7)	15 (12.3)	10 (8.2)	10 (8.2)	2 (1.6)	0 (0.0)
	388 (58.5)	163 (24.6)	69 (10.4)	30 (4.5)	5 (0.8)	8 (1.2)
	473 (60.3)	178 (22.7)	79 (10.1)	40 (5.1)	7 (0.9)	8 (1.0)
Egg & egg preparations	52 (42.6)	15 (12.3)	26 (21.3)	21 (17.2)	4 (3.3)	4 (3.3)
	99 (14.9)	83 (12.5)	169 (25.5)	222 (33.5)	42 (6.3)	48 (7.2)
	151 (19.2)	98 (12.5)	195 (24.8)	243 (31.0)	46 (5.9)	52 (6.6)
Poultry	71 (58.2)	12 (9.8)	13 (10.7)	22 (18.0)	3 (2.5)	1 (0.8)
	114 (17.2)	114 (17.2)	247 (37.3)	171 (25.8)	10 (1.5)	7 (1.1)
	185 (23.6)	126 (16.1)	260 (33.1)	193 (24.6)	13 (1.7)	8 (1.0)
Meat	85 (69.7)	16 (13.1)	8 (6.6)	11 (9.0)	0 (0.0)	2 (1.6)
	282 (42.5)	184 (27.8)	138 (20.8)	51 (7.7)	6 (0.9)	2 (0.3)
	367 (46.8)	200 (25.5)	146 (18.6)	62 (7.9)	6 (0.8)	4 (0.5)
Nuts & seeds	0 (0.0)	4 (3.3)	18 (14.8)	32 (26.2)	9 (7.4)	59 (48.4)
	21 (3.2)	30 (4.5)	130 (19.6)	208 (31.4)	50 (7.5)	224 (33.8)
	21 (2.7)	34 (4.3)	148 (18.9)	240 (30.6)	59 (7.5)	283 (36.1)
Milk & dairy & products	0 (0.0)	0 (0.0)	1 (0.8)	4 (3.3)	2 (1.6)	115 (94.3)
	6 (0.9)	7 (1.1)	13 (2.0)	32 (4.8)	19 (2.9)	586 (88.4)
	6 (0.8)	7 (0.9)	14 (1.8)	36 (4.6)	21 (2.7)	701 (89.3)
Coffee	58 (47.5)	10 (8.2)	17 (13.9)	8 (6.6)	20 (16.4)	9 (7.4)
	364 (54.9)	17 (2.6)	55 (8.3)	24 (3.6)	123 (18.6)	80 (12.1)

Food groups	Frequency of intake of food group					
	<1 / month	< 1 / week	1-2 / week	3-5 / week	6-7 times per week	>7 times per week
	N (%)					
	422 (53.8)	27 (3.4)	72 (9.2)	32 (4.1)	143 (18.2)	89 (11.3)
Fried and fast food	1 (0.8)	7 (5.7)	4 (3.3)	27 (22.1)	18 (14.8)	65 (53.3)
	13 (2.0)	22 (3.3)	55 (8.3)	180 (27.1)	88 (13.3)	305 (46.0)
	14 (1.8)	29 (3.7)	59 (7.5)	207 (26.4)	106 (13.5)	370 (47.1)
Added sugar, SSB ^a and high sugar products	0 (0.0)	0 (0.0)	1 (0.8)	9 (7.4)	2 (1.6)	110 (90.2)
	3 (0.5)	6 (0.9)	14 (2.1)	34 (5.1)	22 (3.3)	584 (88.1)
	3 (0.4)	6 (0.8)	15 (1.9)	43 (5.5)	24 (3.1)	694 (88.4)
Nutrient enriched beverage supplements	69 (56.6)	7 (5.7)	9 (7.4)	3 (2.5)	25 (20.5)	9 (7.4)
	499 (75.3)	12 (1.8)	24 (3.6)	20 (3.0)	76 (11.5)	32 (4.8)
	568 (72.4)	19 (2.4)	33 (4.2)	23 (2.9)	101 (12.9)	41 (5.2)
High salt products	22 (18.0)	15 (12.3)	24 (19.7)	28 (23.0)	14 (11.5)	19 (15.6)
	152 (22.9)	65 (9.8)	133 (20.1)	111 (16.7)	105 (15.8)	97 (14.6)
	174 (22.2)	80 (10.2)	157 (20.0)	139 (17.7)	119 (15.2)	116 (14.8)
Visible fat ^b	30 (24.6)	11 (9.0)	28 (23.0)	10 (8.2)	27 (22.1)	16 (13.1)
	304 (45.9)	72 (10.9)	118 (17.8)	58 (8.7)	76 (11.5)	35 (5.3)
	334 (42.5)	83 (10.6)	146 (18.6)	68 (8.7)	103 (13.1)	51 (6.5)

Coloured boxed indicate intakes in **Cloudnine hospital**, **Baptist hospital** and both **combined**

^a SSB = Sugar Sweetened Beverages.

^b Visible fat includes clarified butter / ghee and butter.

Table 3.8 presents median monthly food group intake frequencies. At Cloudnine, the median intake of pulse and lentil preparations, cooked vegetables, fresh fruits and fruit juices, nuts and seeds, milk and dairy products, fried and fast food and visible fat was higher. At Baptist, median intakes of milled cereals, wholegrain cereals, cooked green leafy vegetables, poultry, sugar and SSB was higher, with the boxplots conveying the same (figures 3.2 & 3.3).

Table 3.8: Median frequency of peri-conceptional intake of food groups per month (n=785)

Food groups	Cloudnine hospital	Baptist Hospital	Both hospitals combined
	N = 122	N = 663	N = 785
	Median (IQR)		
Milled cereals & products	33.5 (27.3, 41.5)	38.2 (31.0, 46.0)	37.5 (30.2, 45.2)
Whole grain cereals	2.5 (0.5, 7.5)	5.0 (0.7, 8.0)	4.0 (0.7, 7.7)
Pulse and lentil preparations	7.3 (3.2, 10.1)	4.0 (2.2, 6.0)	4.0 (2.5, 7.0)
Salads & raw vegetables	3.7 (1.9, 8.8)	3.0 (1.2, 5.5)	3.0 (1.2, 6.2)
Cooked vegetables	10.2 (6.7, 15.0)	9.0 (6.0, 13.5)	9.5 (6.2, 13.8)
Potato containing dishes	2.2 (1.0, 3.5)	2.5 (1.2, 3.7)	2.2 (1.2, 3.7)
Potato palya	0.5 (0.0, 1.0)	0.7 (0.2, 1.0)	0.7 (0.2, 1.0)
Cooked Green leafy	2.3 (1.2, 4.0)	3.0 (2.0, 4.7)	3.0 (2.0, 4.5)
Fresh fruit and fruit juices	25.1 (16.6, 45.3)	23.2 (15.2, 35.5)	23.5 (15.2, 37.1)
Fish & seafood	0.0 (0.0, 0.5)	0.0 (0.0, 0.5)	0.0 (0.0, 0.5)
Egg & egg preparations	0.5 (0.0, 2.0)	2.0 (0.7, 4.0)	1.7 (0.5, 3.5)
Poultry	0.0 (0.0, 1.7)	1.5 (0.5, 2.2)	1.2 (0.2, 2.2)
Meat	0.0 (0.0, 0.2)	0.2 (0.0, 1.0)	0.2 (0.0, 1.0)
Nuts & seeds	7.0 (2.7, 12.2)	4.0 (2.0, 9.0)	4.2 (2.0, 10.0)
Dairy products	20.0 (14.7, 26.9)	18.5 (12.5, 26.2)	18.7 (13.0, 26.3)
Coffee	0.2 (0.0, 3.5)	0.0 (0.0, 7.0)	0.0 (0.0, 7.0)
Fried and fast food	8.0 (4.1, 11.3)	6.5 (3.5, 11.0)	6.7 (3.5, 11.0)
Added sugar, SSB & high sugar products	18.5 (10.5, 25.5)	0.0 (0.0, 0.0)	20.0 (12.2, 27.7)
Nutrient enriched beverage supplements*	0.0 (0.0, 7.0)	20.2 (12.7, 28.5)	0.0 (0.0, 1.0)
High salt products	2.1 (0.5, 5.5)	2.0 (0.2, 7.0)	2.0 (0.2, 7.0)
Visible fat	2.0 (0.1, 7.0)	0.2 (0.0, 2.5)	0.5 (0.0, 3.0)

*Includes usage of nutrient enriched beverage supplements reported by women in FFQ only.

Figure 3.2: A boxplot comparison of weekly food intake frequency among women at Baptist and Cloudnine hospitals (n=785)

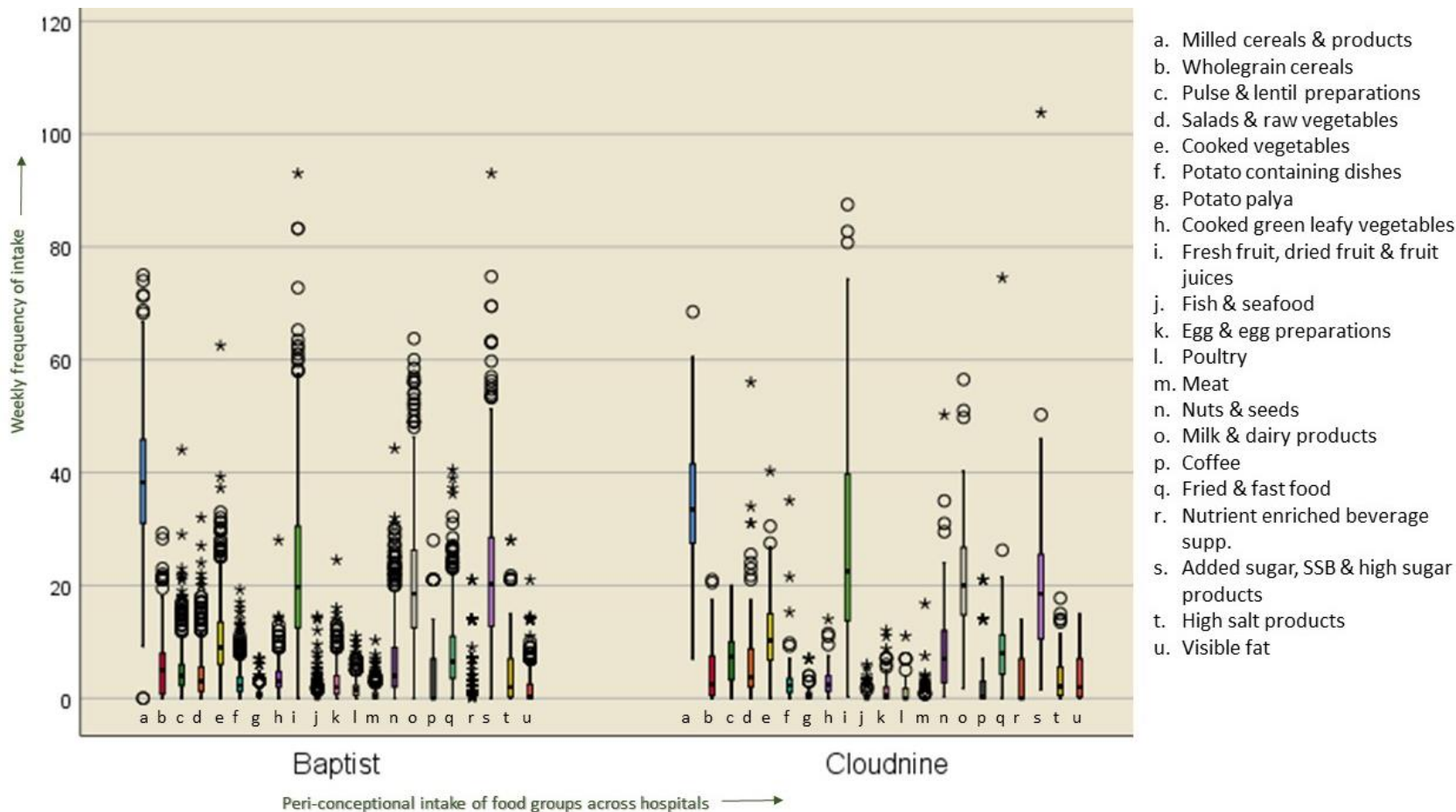


Figure 3.3: A boxplot showing weekly frequency of intake of food groups of women from both hospitals combined (n=785)

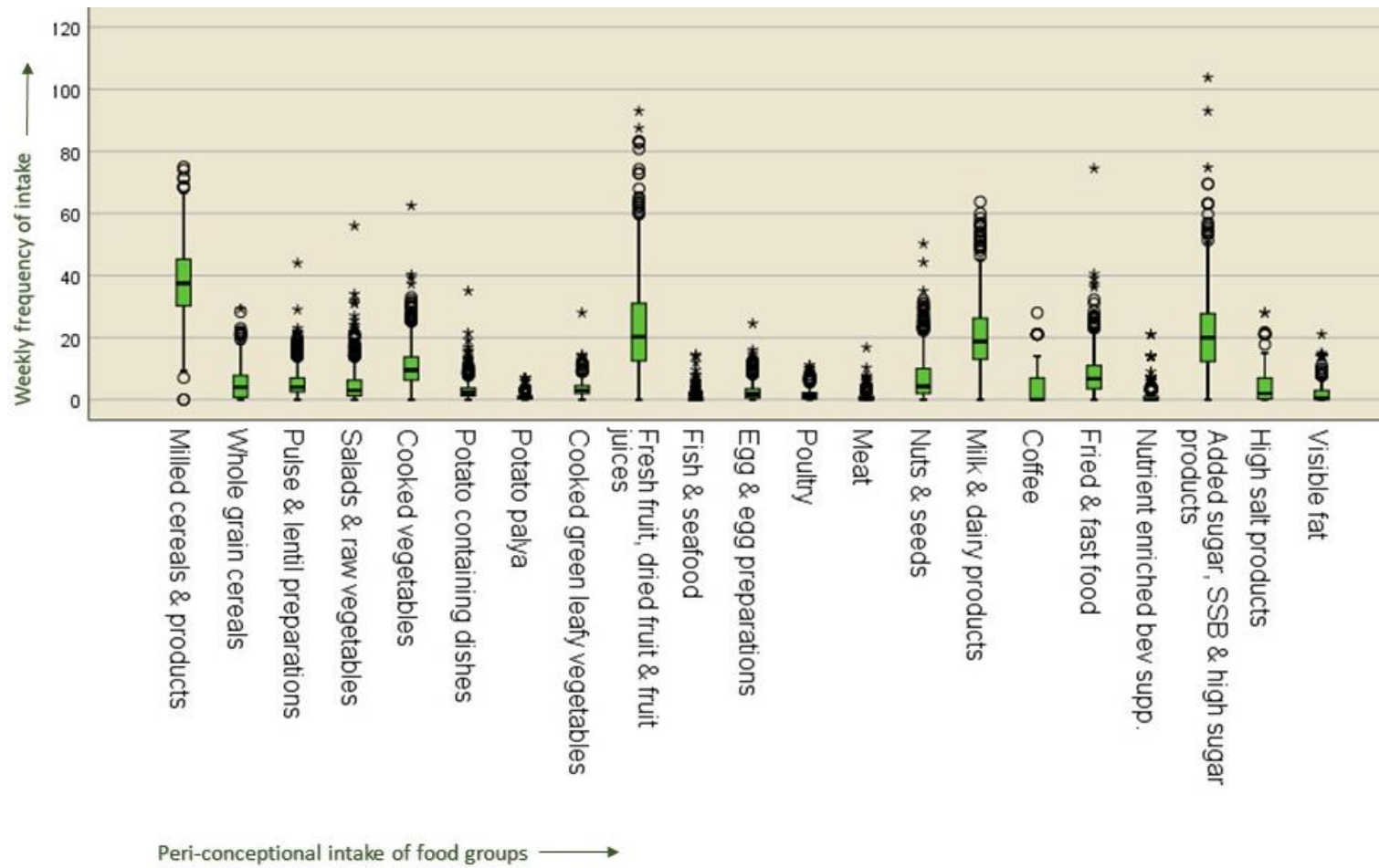


Table 3.9 describes physical activity behaviour at recruitment. Women in Baptist in general were more physically active than women in Cloudnine. Women in Baptist did more vigorous and moderate intensity physical activity. A fifth of the women reported going for light walks of ≥ 150 minutes/ week as per pregnancy recommendations (RCOG UK, 2017; WHO 2010). Half of Cloudnine women had a screen time of ≥ 240 minutes/day, twice that of Baptist (median 240 vs. 120). Half of Cloudnine women had a daily sitting time of at least 8 hours/day in contrast to 22% at Baptist.

Table 3.9: Physical activity and sedentary behaviour of the women at recruitment (n=785)

	Cloudnine hospital N = 122	Baptist hospital N = 663	Both hospitals combined N = 785
	N (%)		
Physical activity calculated from IPAQ scores			
Low ^a	66 (54.1)	158 (23.8)	224 (28.5)
Moderate ^b	22 (18.0)	158 (23.8)	180 (22.9)
High ^c	34 (27.9)	347 (52.3)	381 (48.5)
Categories of total light walking per week (minutes) ^d			
No walking/ light physical	51 (41.8)	318 (48.3)	369 (47.3)
Between 1 and 150 minutes	44 (36.1)	215 (32.7)	259 (33.2)
Above 150 minutes per week	27 (22.1)	125 (19.0)	152 (19.5)
Categories of Sedentary behaviour per day (minutes)			
Median (IQR) daily screen time*	240.0 (120.0, 435.0)	120.0 (60.0, 270.0)	120.0 (60.0, 300.0)
Categories of daily screen		N (%)	
< 240 minutes / < 4 hours	65 (53.3)	496 (74.8)	561 (71.5)
> 240 minutes / > 4 hours	57 (46.7)	167 (25.2)	224 (28.5)
Daily duration of sitting (minutes) Median (IQR)	420.0 (262.5, 540.0)	240.0 (120.0, 360.0)	240.0 (120.0, 420.0)
Categories of daily duration of		N (%)	
Up to 120 minutes	13 (10.7)	210 (31.7)	223 (28.4)
Up to 240 minutes	17 (13.9)	159 (24.0)	176 (22.4)
Up to 360 minutes	30 (24.6)	147 (22.2)	177 (22.5)
Up to 480 minutes & more	62 (50.8)	147 (22.2)	209 (26.6)

^{a, b, c} Definitions on page 98.

^d Categorisation of light walking levels based on recommendations of exercise in pregnancy from RCOG, UK, 2017 and WHO, 2010.

* Screen time refers to the time spent in front of digital screens (television, computer, electronic tablets and mobile phones).

Table 3.10 describes nutraceutical tablet and supplement usage recorded at recruitment. There were multiple combinations of nutraceutical tablets and

supplements prescribed in both hospitals. Most women used folic acid, iron and calcium, though some used no supplements. The median (IQR) for the duration of intake of folic acid supplements was 2 (1- 4) months (data not shown). A third (more in Cloudnine) were taking nutrient-enriched beverage supplements.

Table 3.10: Nutraceutical tablet and supplement usage recorded at recruitment (n=785)

Type of nutraceutical tablet/ supplement taken	Cloudnine hospital N = 122	Baptist hospital N = 663	Both hospitals combined N = 785
	N (%)		
Folic acid only	65 (53.3)	417 (62.9)	482 (61.4)
Folic acid, iron, calcium	10 (8.2)	22 (3.3)	32 (4.1)
Iron, Calcium	33 (27.0)	127 (19.2)	160 (20.4)
Calcium only	4 (3.3)	4 (0.6)	8 (1.0)
Folic acid and Calcium	2 (1.7)	8 (1.2)	10 (1.2)
Iron only	1 (0.8)	1 (0.2)	2 (0.3)
Folic acid and Iron	1 (0.8)	6 (0.9)	7 (0.9)
Not using any tablets	6 (4.9)	78 (11.7)	84 (10.7)
Use of nutrient enriched supplements with milk			
Nutrient enriched beverage supplements*	Yes = 63 (51.6) No = 59 (48.4)	Yes = 184 (27.8) No = 479 (72.2)	Yes = 247 (31.5) No = 538 (68.5)
*Nutrient enriched beverage supplements include energy-protein supplements.			

3.4. Gestational diabetes prevalence

Table 3.11 shows that the prevalence of GDM in both the hospitals by different methods. Using the OGTT data alone, the prevalence was higher in Baptist, but including the GCT method it was observed that Cloudnine women had a similar GDM prevalence (16%).

Table 3.11: Prevalence of GDM based on elevated 50-gram GCT and 75-gram OGTT values (n=714)

Hospital	Total women testing for glucose tolerance	GDM prevalence N	%
Cloudnine (including GCT, OGTT & FBS/PPBS)	112	18	16.0
Cloudnine (OGTT only)	80	7	8.7
Cloudnine (GCT only)	31	11	35.4
Cloudnine (FBS/PPBS only)	1	0	-
Baptist (including GCT, OGTT & FBS/PPBS)	602	139	23.1

Baptist (OGTT only)	597	139	23.2
Baptist (GCT only)	4	0	-
Baptist (FBS/PPBS only)	1	0	-
Combined	714	157	21.9

Table 3.12 shows that there was no major difference in key characteristics including age, SES, BMI and body weight between women who were followed up for glucose tolerance and those who dropped out of the study after recruitment.

Table 3.12: Differences in age, BMI and SES between women who were followed up for glucose tolerance and women who dropped out of the study after recruitment

Key population characteristics	Study participants		p*
	Followed for glucose tolerance n=714	Not followed up for glucose tolerance n=71	
	Median (IQR)		
Age (years)	26.61 (23.42, 29.65)	25.73 (23.21, 28.92)	0.29
SLI score	38 (33, 43)	37 (31, 42)	0.07
Monthly income (INR)	30,000 (15,000, 60,000)	31,000 (19,500, 52,500)	0.80
BMI (Kg/m ²)	23.23 (20.50, 26.61)	23.24 (20.42, 26.37)	0.57
Weight at recruitment (Kg)	57.0 (50.20, 66.15)	57.5 (47.17, 65.82)	0.54
*p value using Mann Whitney's test for differences			
Missing N: Income = 135, BMI = 22, weight at recruitment = 21			

3.5. Discussion

Differences between hospitals: There were differences in health, wealth, diets, physical activity and GDM prevalence between the hospitals.

Women in Cloudnine were older, probably because they had delayed marriage and conception to obtain higher education and establish a career. Cloudnine women were more adipose (higher median BMI at recruitment). Gravidity was similar between hospitals, with Cloudnine having twice the miscarriage rate possibly because risk of miscarriage increases with age (Magnus et al., 2019). A positive family history of T2DM in Cloudnine was twice that in Baptist. PCOS and thyroid problems were more common in Cloudnine.

We expected to see a difference in the income, SLI score, education and occupation between the hospitals. Median income in Cloudnine was four times that of Baptist and mean SLI score was also higher. A large percentage in both hospitals were homemakers, but more women in Cloudnine had acquired post

graduate education and worked as high-level and mid-level professionals. There were fewer women from lower income groups than expected, with only 12.2 % of women having an income below INR 10,000 and none below the poverty line (annual income <INR 20,000). The NFHS has not been updated to reflect inflation trends in the country, and so actual Middle-Income Groups may be overestimated as High-Income Groups (Lahariya, 2016). A fifth of women did not know or would not disclose their family income. This could be due to a fear of current stringent government policies, to bring transparency in incomes, or a lack of empowerment in household financial decision-making.

Most women had electrified pucca houses with separate kitchens, used LPG as the cooking fuel and had piped drinking water. More women at Cloudnine had flush type toilets than at Baptist. Most women owned assets such as cot, mattress, pressure cooker, chair, table, clock and electric fan, however there were differences in some expensive household assets such as air conditioner, refrigerator, washing machine, plasma TV, car, internet and computer with more Cloudnine women owning these. Interestingly most women did not own inexpensive household assets such as sewing machines, bicycles and landline telephones, with the exception of radios, which are inexpensive but trendy, with more Cloudnine women using them.

Baptist is a Christian missionary hospital and we expected more Christian women but 16.1 % were Christian and 75.9% were Hindu. These figures mirror census data, whereby Christians comprise 2.3% of the Indian population (Census of India, 2011).

Peri-conceptional diets of women: Women overall consumed milled cereals and products, cooked vegetables, fresh fruit, dried fruit and fruit juices, dairy products, nuts and seeds, fried and fast food and sugar frequently; and wholegrain cereals, pulses and lentils, green vegetables, salads and raw vegetables, egg, poultry and meat less frequently. Milled rice preparations formed the staple with most eating them more than once daily, as expected in a South Indian diet. A quarter ate wholegrain cereals in the form of finger millet, wheat and red rice with lesser intakes of cereal grains such as bajra, jowar, maize and corn. Only a quarter consumed pulses and lentil preparations more than once daily. The traditional Indian diet has always included pulses as a daily staple but intakes have reduced drastically in the

past decade, because of increasing prices (Sekher et al., 2017). For example, toor dal, (a staple pulse) costs INR 220/kg.

Cooked vegetables such as potato, carrot, beetroot, gourds, onion, cabbage and cauliflower were frequently consumed. Green leafy vegetables (drumstick, fenugreek, spinach, cabbage, cauliflower and amaranth) were consumed by only about 50% of the women, 3-5 times/ week, and less. This was surprising because greens are inexpensive, and commonly thought of as highly nutritious. Women reported that it was challenging to get clean greens in urban Bangalore and believed that greens were contaminated with pesticides and germs that cause diarrhoea and intestinal worms.

Consumption of fresh fruit, fruit juices and dried fruit was high with 90% consuming these daily. Nuts and seeds were consumed frequently (40% having them >1/day) even though nuts are expensive (INR 900/ Kg).

Vegetarian cultural beliefs are strong in India (Sharma, 2019) and more than 50% women were vegetarian and reported not consuming egg, fish, poultry and meat. Additionally, even women who consumed these foods didn't eat them frequently enough to meet recommendations. For example, the majority eat egg and meat only once a week and fish less than once a week.

Gestational Diabetes prevalence: The prevalence of GDM by OGTT was higher at Baptist, but this could be due to a smaller sample size in Cloudnine and in fact Cloudnine had many women diagnosed as GDM using the GCT, among whom the prevalence was 35.4%. Additionally, it is common for women with PCOS in Cloudnine to take metformin or myo-inositol, for treating irregular menstrual cycles or sub-fertility, agents known to improve glucose tolerance (Unfer, 2017), although these women were not taking any medications when we recruited them. GDM prevalence has been compared with other studies in India on pages 8 & 158.

Methodological challenges and approaches taken: Urban and rural classifications were based on the pin codes of the participant's residence using the government of Karnataka's pincode directory (Open Government Data, Platform India, 2019). The urban-rural classification is problematic in India, because it is based on questionable criteria, e.g. populations >100000 designated 'urban'. For this reason, there is a failure to recognise already urban areas as urban by the Indian Census, which identifies only 31% of India

as urban. However, we get a different picture when we look at a 2016 World Bank report, based on an agglomeration index by Uchida and Nelson, which sees India to be 47% urban. This index is based on three criteria: population density, the population of a “large” urban centre, and travel time to that large urban centre (Uchida and Nelson, World Bank report, 2009)

Ideally an urban-rural classification should be based on size of area, population density and the primary occupation of the working population, but I used the available local government’s system. This system has its drawbacks, but to address some of its caveats and to check if women have been correctly classified as rural, I analysed the characteristics of my study’s rural population. My analysis found that a larger percent of women from rural Bangalore compared to urban Bangalore: lived in joint families (60 vs. 40%), lived in self-owned houses (53.6% vs. 31.3%), owned agricultural land (63 vs. 27%), or owned farming tools such as tractors. Additionally, rural women owned fewer expensive household assets such as: plasma TV (52.4 vs. 62.5%), broadband internet (28.3 vs. 57.0%), refrigerator (69.5 vs. 80 %), air conditioner (3.0 vs. 13.4%), washing machine (40.8 vs. 65.9%) and computer (31.8 vs. 64.2%). There were no differences in ownership of a water pump (51.9 vs. 47.1%), perhaps because water pumps are used in urban areas equally these days, because of water scarcity. This analysis showed that there are lifestyle differences between urban and rural women despite similar median SLI scores in both groups (39 and 38 of rural and urban respectively). However, the median monthly income of urban women was higher (INR 35,000 vs. 20,000). Based on these findings above, it is reasonable to say that the rural women did have expected rural characteristics, different from urban women.

Study strengths and weaknesses: Socioeconomic status (SES), SES is a challenging factor to measure because it encompasses education, occupation, societal status, income and household assets. (Lahariya, 2016). SES is a recognized risk factor for obesity and type 2 diabetes, but is less clearly linked to GDM (Bo et al., 2002; Janghorbani et al., 2006 and Berkowitz et al., 1992). Few studies in India have included low, middle and high income groups so we chose two different hospitals, to increase the likelihood of obtaining a diverse sample. Women did not have any major illnesses based on their medical history with the exception of Hyperemesis Gravidarum (severe vomiting) in a few. However, some had a medical history of PCOS (10%) and

hypothyroidism (18%). Largely, women conceived naturally and the study population had a mix of primi- and multigravid women. Over half were in the normal BMI category with about 10% underweight and 35% overweight and obese. This reflects the double burden that India as a transitioning country faces, though the proportion of underweight women in my study is lower than the national average of 23% (NFHS 4, 2014-15).

We initially targeted 3 hospitals and planned to have equal numbers of low, middle and high SES but there were delays with ethics procedures at Vanivilas hospital (serving the lowest income groups), which meant it was not possible to proceed. The target sample size was 1000 but we achieved 785 in the time available. We could not have an equal representation from the lowest income groups, as Baptist and Cloudnine generally represent middle and high-income groups, and Vanivilas (caters to low/very low-income groups) was not part of our study. It was challenging to recruit women from high income groups due to many women being reluctant to participate due to lack of time, therefore in Cloudnine we could recruit only 122 women. GDM prevalence of 16% in Cloudnine compared to 23% in Baptist could be because of the smaller sample size in Cloudnine, thereby making the prevalence less reliable.

Assessment of physical activity was challenging in the study. We had to adapt the IPAQ to the Indian scenario for less known household activities including: yard work, floor mopping and sweeping, washing clothes, cooking, lifting heavy vessels and carrying toddlers. We asked women if they breathed hard while doing these activities (one of the criteria of assessing activity type in the IPAQ) (IPAQ group, 2005). If yes, we graded the activity as vigorous or moderate. These assessments inevitably rely on subjective perceptions which could have led to less accurate IPAQ scores. To overcome this, I used light walking per week, for further analyses, which is an activity that is easy for women to recall.

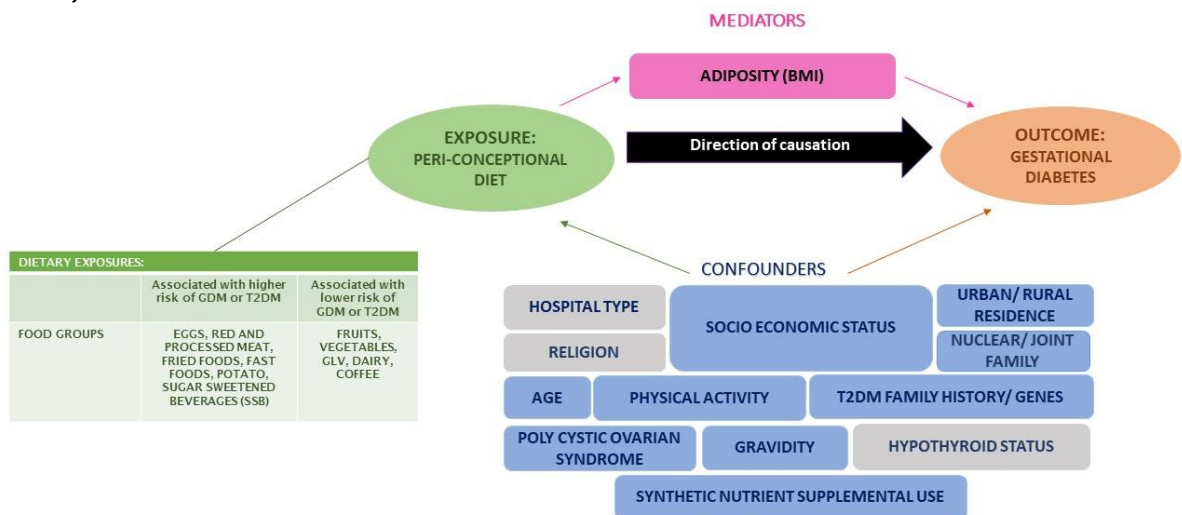
Chapter 4

Population characteristics related to the exposure ‘peri-conceptual diet’ represented as food groups

4.1. Background and aims

‘Peri-conceptual diet’ is the exposure and ‘GDM development’ is the outcome of my study, but before exploring the association between ‘diet’ and GDM, I shall first study if diet is associated with the population characteristics shown in the concept diagram (figure 4.1). If these are associated with both diet and GDM, they may act as confounders, that could distort diet-GDM associations and should be adjusted for. This chapter will study population characteristics related to the diet represented by food groups.

Figure 4.1: Concept diagram exploring causal associations between diet and GDM, drawn from the literature



4.2. Population characteristics as predictors of weekly frequency of peri-conceptional intake of the food groups

I began by looking at the difference in medians of weekly frequency of food group intakes among women in each category of the population characteristic being studied, using non-parametric tests. I used Mann-Whitney tests for 2-category variables such as hospital type (Baptist vs Cloudfine) to see if the reported weekly frequency of intakes of food groups was significantly different between hospitals. However non-parametric tests are problematic because they tell us if there is a statistical difference between two groups, but not the magnitude of the difference. There is a problem of tied ranks with similar values (expected in food frequency data) and hence less likelihood of detecting differences. Also, these tests do not allow adjustment for multiple variables. Therefore, I next used regression analysis. I used different types of regression analysis based on the type of outcome variable (weekly frequency of intake of food groups): linear regression for continuous variables, logistic regression for binary variables, and ordinal logistic regression for scalar categories. Additionally, in every regression table, I have presented the medians which are useful to relate to real life intakes (difficult in regression after transformation and z-standardisation).

4.2.1. Hospital (Baptist vs. Cloudfine)

Women at Baptist hospital ate milled cereals & products, cooked green leafy vegetables, fish & seafood, egg & egg preparations, poultry and meat more often than women at Cloudfine (table 4.1, Appendix P, page 337). Women at Cloudfine had more frequent intake of pulse & lentil preparations, salads & raw vegetables, fresh fruit, dried fruit & fruit juices, nuts & seeds, nutrient enriched beverage supplements and visible fat. To give an example of the magnitude of these associations: women from Cloudfine hospital consumed 0.34 SD higher frequency of nuts & seeds than women from Baptist hospital. Women from Baptist hospital had a higher intake of egg & egg preparations (median weekly frequency of intake 2.0 compared with 0.5 in Cloudfine, Table 4.1, page 337); the odds ratio for being one category higher for egg intake was 0.37 (95% CI: 0.25 to 0.54) for women from Cloudfine hospital compared to Baptist. To explain this further, women from Cloudfine Hospital were 63% less

likely than women from Baptist to be in category 2 rather than category 1, or category 3 rather than category 2.

4.2.2. Religion

Table 4.2 shows the regression analysis of religion as a predictor of weekly frequency of intake of food groups. Hindu women are the reference group. Jain women did not eat fish, egg, poultry and meat and hence were not included in the analysis of those food groups.

Hindu women had the highest intakes of milled cereals & products, wholegrain cereals and cooked green leafy vegetables. Christian women had the most frequent intakes of fish & seafood and least frequent intake of pulse & lentil preparations and salads & raw vegetables. Muslim women had the highest frequency of intake of potato palya, egg and egg preparations, poultry and meat and the lowest frequency of intakes of dairy. Jain women had the highest intake of pulse & lentil preparations, salads & raw vegetables, fresh fruit, dried fruit and fruit juices, fried & fast food, nutrient enriched beverage supplements and visible fat and lowest intake of milled cereals & products, potato palya and cooked green leafy vegetables. To give an idea of the magnitude of these associations: the odds ratio for being one category higher for fish & seafood consumption was 5.42 (95% CI 3.67, 8.00) for Christian women compared to the reference group. This could be explained further as most Hindu women and all Jain women reported eating no fish at all. In contrast, most Christian and Muslim women ate fish at least once per week, and almost 40% of Christian women ate fish twice a week or more (Table 4.2). Per category of fish intake, Christian women was 5 times more likely than Hindu women to be in a higher category.

Table 4.2: Regression analysis of participant religion as a predictor of frequency of intake of food groups (n=776*)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2, 3})	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2, 3}	Predictor: Participant religion (Hindu = 0, Christian = 1, Muslim = 2, Jain = 3)		
			β ¹ / Odds ratio ^{2, 3}	95% CI	p
Milled cereals & products ¹ : Continuous variable, z-standardised; units = SD					
Hindu	38.0 (31.0, 45.2)	607 (78.2)	Reference	-	-
Christian	36.2 (28.0, 45.0)	111 (14.3)	-0.21	-0.42, -0.01	0.03
Muslim	36.7 (31.2, 43.5)	47 (6.0)	-0.09	-0.39, 0.20	0.55
Jain	30.0 (25.5, 43.2)	11 (1.5)	-0.47	-1.07, -0.12	0.19
Wholegrain cereals ² : Binary variable, 0 = none* & 1 = any					
Hindu	7.0 (1.2, 8.0)	0=66 (10.9) 1=541 (89.1)	Reference	-	-
Christian	1.2 (0.2, 4.0)	0=23 (20.7) 1=88 (79.3)	0.47	0.28, 0.79	0.004
Muslim	0.7 (0.0, 7.0)	0=18 (38.3) 1=29 (61.7)	0.20	0.10, 0.37	<0.001
Jain	0.5 (0.0, 3.0)	0=3 (27.3) 1=8 (72.7)	0.32	0.08, 1.26	0.103
Pulse & lentil preparations ¹ : Continuous variable, log (x+1) transformed and z- standardised; units = SD					
Hindu	4.0 (2.7, 7.5)	607 (78.2)	Reference	-	-
Christian	3.0 (1.2, 5.0)	111 (14.3)	-0.55	-0.75, -0.35	<0.001
Muslim	3.5 (2.2, 6.0)	47 (6.0)	-0.28	-0.58, 0.01	0.05
Jain	0.5 (0.0, 2.0)	11 (1.5)	0.68	0.09, 1.27	0.02
Salads & raw vegetables ¹ : Continuous variable, log (x+1) transformed and z- standardised; units = SD					
Hindu	3.0 (1.2, 6.5)	607 (78.2)	Reference	-	-
Christian	2.0 (0.7, 5.0)	111 (14.3)	-0.30	-0.50, -0.09	0.003
Muslim	3.2 (2.0, 7.0)	47 (6.0)	0.23	-0.06, 0.52	0.13
Jain	7.0 (4.0, 16.0)	11 (1.5)	0.73	0.14, 1.32	0.01
Cooked vegetables ¹ : Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Hindu	9.5 (6.2, 14.0)	607 (78.2)	Reference	-	-
Christian	9.5 (6.0, 14.2)	111 (14.3)	-0.07	-0.27, 0.13	0.51
Muslim	7.5 (5.5, 10.0)	47 (6.0)	-0.25	-0.55, 0.04	0.09
Jain	8.0 (4.5, 11.2)	11 (1.5)	-0.24	-0.84, 0.35	0.42
Potato containing dishes ² : Binary variable, 0 = low (<1/wk)* & 1 = high (>1/wk)					
Hindu	2.0 (1.2, 3.5)	0 = 143 (23.6) 1 = 464 (76.4)	Reference	-	-
Christian	2.0 (1.0, 3.7)	0 = 31 (27.9) 1 = 80 (72.1)	0.80	0.51, 1.25	0.32
Muslim	3.0 (2.0, 4.5)	0 = 7 (14.9) 1 = 40 (85.1)	1.76	0.77, 4.02	0.18
Jain	2.0 (0.7, 3.5)	0 = 4 (36.4) 1 = 7 (63.6)	0.54	0.16, 1.87	0.14
Potato palya ² : Binary variable, 0 = low (<1/wk)* & high (1 = ≥1/wk)					
Hindu	0.7 (0.2, 1.0)	0 = 319 (52.6) 1 = 288 (47.4)	Reference	-	-
Christian	0.5 (0.2, 1.0)	0 = 62 (55.9)	0.88	0.58, 1.32	0.52

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Participant religion (Hindu = 0, Christian = 1, Muslim = 2, Jain = 3)		
			β^1 / Odds ratio ^{2,3}	95% CI	p
Muslim	1.0 (0.5, 2.0)	1 = 49 (44.1) 0 = 15 (31.9) 1 = 32 (68.1)	2.36	1.25, 4.45	0.008
Jain	0.2 (0.0, 0.5)	0 = 9 (81.8) 1 = 2 (18.2)	0.25	0.05, 1.15	0.07
Cooked Green leafy vegetables ¹ : Continuous variable, square root transformed and z-standardised; units = SD					
Hindu	3.0 (2.0, 5.0)	607 (78.2)	Reference	-	-
Christian	2.7 (1.7, 4.0)	111 (14.3)	-0.23	-0.43, -0.03	0.02
Muslim	2.7 (1.0, 4.0)	47 (6.0)	-0.32	-0.61, -0.02	0.03
Jain	2.0 (0.5, 2.5)	11 (1.5)	-0.99	-1.59, -0.41	0.001
Fresh fruit, dried fruit & fruit juices ¹ : Continuous variable, square root transformed and z-standardised; units = SD					
Hindu	23.2 (15.2, 37.7)	607 (78.2)	Reference	-	-
Christian	22.2 (14.2, 32.0)	111 (14.3)	-0.14	-0.34, 0.06	0.17
Muslim	29.0 (17.0, 39.2)	47 (6.0)	0.29	0.001, 0.59	0.05
Jain	37.7 (23.2, 54.5)	11 (1.5)	0.69	0.09, 1.28	0.02
Nuts & seeds ¹ : Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Hindu	4.0 (2.0, 9.0)	607 (78.2)	Reference	-	-
Christian	4.7 (2.0, 11.0)	111 (14.3)	0.07	-0.13, 0.27	0.50
Muslim	8.2 (2.0, 15.0)	47 (6.0)	0.27	-0.02, 0.56	0.07
Jain	8.0 (4.0, 10.2)	11 (1.5)	0.39	-0.21, 0.98	0.20
Fish & seafood ³ : 3 categories variable, 0 = none, 1 = low(<1/wk) & 2 = high (≥1-3/ wk)					
Hindu	0.0 (0.0, 0.2)	0 = 417 (68.7) 1 = 113 (18.6) 2 = 77 (12.7)	Reference	-	-
Christian	0.5 (0.0, 1.5)	0 = 29(26.1) 1 = 40 (36.0) 2 = 42 (37.8)	5.42	3.67, 8.00	<0.001
Muslim	0.2 (0.0, 1.0)	0 = 12 (25.5) 1 = 22 (46.8) 2 = 13 (27.7)	4.40	2.52, 7.67	<0.001
Jain	0.0 (0.0, 0.0)	0 = 11 (100.0) 1 = 0 (0.0) 2 = 0 (0.0)	Don't consume**	-	-
Egg & egg preparations ³ : 3 categories variable, 0 = low (≤1/wk), 1 = medium (>1 - 3/wk) & 2 = high (> 3/wk)					
Hindu	1.5 (0.2, 3.2)	0 = 262 (43.2) 1 = 192 (31.6) 2 = 153 (25.2)	Reference	-	-
Christian	3.0 (1.7, 4.5)	0 = 19 (17.1) 1 = 45 (40.5) 2 = 47 (42.3)	2.71	1.86, 3.97	<0.001
Muslim	3.0 (1.7, 5.0)	0 = 9 (19.1) 1 = 16 (34.0) 2 = 22 (46.8)	2.94	1.68, 5.15	<0.001

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Participant religion (Hindu = 0, Christian = 1, Muslim = 2, Jain = 3)		
			β^1 / Odds ratio ^{2,3}	95% CI	p
Jain	0.0 (0.0, 0.0)	0 = 11 (100.0) 1 = 0 (0.0) 2 = 0 (0.0)	Don't consume**	-	-
Poultry ³ : 4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium (>1 -2/wk) & 3 = high (> 2 /wk)					
Hindu	1.0 (0.0, 2.0)	0 = 165 (27.2) 1 = 157 (25.9) 2 = 144 (23.7) 3 = 141 (23.2)	Reference	-	-
Christian	1.7 (1.0, 2.7)	0 = 6 (5.4) 1 = 28 (25.2) 2 = 33 (29.7) 3 = 44 (39.6)	2.68	1.84, 3.88	<0.001
Muslim	2.2 (1.2, 3.0)	0 = 1 (2.1) 1 = 9 (19.1) 2 = 13 (27.7) 3 = 24 (51.1)	4.10	2.33, 7.23	<0.001
Jain	0.0 (0.0, 0.0)	0 = 11 (100.0) 1 = 0 (0.0) 2 = 0 (0.0) 3 = 0 (0.0)	Don't consume**	-	-
Meat ³ : 3 categories variable, 0 = none, 1 = low (<1 / week) & 2 = medium (≥ 1 / week)					
Hindu	0.0 (0.0, 0.7)	0 = 322 (53.0) 1 = 152 (25.0) 2 = 133 (21.9)	Reference	-	-
Christian	0.5 (0.0, 1.5)	0 = 28 (25.2) 1 = 39 (35.1) 2 = 44 (39.6)	2.84	1.94, 4.15	<0.001
Muslim	2.5 (1.2, 4.5)	0 = 2 (4.3) 1 = 5 (10.6) 2 = 40 (85.1)	22.18	9.74, 50.50	<0.001
Jain	0.0 (0.0, 0.0)	0 = 11 (100.0) 1 = 0 (0.0) 2 = 0 (0.0)	Don't consume**	-	-
Milk & dairy products ¹ : Continuous variable, square root transformed and z-standardised; units = SD					
Hindu	20.0 (14.0, 28.2)	607 (78.2)	Reference	-	-
Christian	15.0 (9.5, 22.5)	111 (14.3)	-0.36	-0.56, -0.16	<0.001
Muslim	16.5 (7.0, 21.2)	47 (6.0)	-0.51	-0.81, -0.22	0.001
Jain	21.0 (16.7, 24.5)	11 (1.5)	0.08	-0.51, 0.67	0.79
Coffee ² : Binary variable, 0 = none* & 1 = any					
Hindu	0.0 (0.0, 7.0)	0 = 317 (52.2) 1 = 290 (47.8)	Reference	-	-
Christian	0.0 (0.0, 7.0)	0 = 58 (52.3) 1 = 53 (47.7)	0.99	0.67, 1.50	0.99
Muslim	0.0 (0.0, 1.0)	0 = 35 (74.5) 1 = 12 (25.5)	0.38	0.19, 0.74	0.004
Jain	0.0 (0.0, 2.0)	0 = 6 (54.5)	0.91	0.28, 3.02	0.88

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Participant religion (Hindu = 0, Christian = 1, Muslim = 2, Jain = 3)		
			β ¹ / Odds ratio ^{2,3}	95% CI	p
1 = 5 (45.5)					
Fried & fast food ¹ : Continuous variable, square root transformed and z-standardised; units = SD					
Hindu	6.7 (3.5, 11.0)	607 (78.2)	Reference	-	-
Christian	5.7 (3.2, 9.7)	111 (14.3)	-0.17	-0.38, 0.03	0.09
Muslim	7.0 (3.7, 12.0)	47 (6.0)	0.10	-0.19, 0.40	0.50
Jain	13.0 (11.2, 19.2)	11 (1.5)	0.90	0.31, 1.50	0.003
Added sugar, SSB & high sugar products ¹ : Continuous variable, square root transformed and z-standardised; units = SD					
Hindu	19.7 (11.7, 27.0)	607 (78.2)	Reference	-	-
Christian	18.5 (14.0, 30.2)	111 (14.3)	0.09	-0.11, 0.30	0.37
Muslim	22.7 (10.0, 33.5)	47 (6.0)	0.15	-0.15, 0.45	0.33
Jain	16.5 (10.7, 7.0)	11 (1.5)	-0.12	-0.72, 0.48	0.69
Nutrient enriched beverage supplements ² : Binary variable, 0 = none* & 1 = any					
Hindu	0.0 (0.0, 0.7)	None = 443(73.0) Any = 164 (27.0)	Reference	-	-
Christian	0.0 (0.0, 0.5)	None = 82 (73.9) Any = 29 (26.1)	0.96	0.60, 1.51	0.85
Muslim	0.0 (0.0, 0.2)	None = 35 (74.5) Any = 12 (25.5)	0.93	0.47, 1.83	0.83
Jain	7.0 (1.0, 7.0)	None = 2 (18.2) Any = 9 (81.8)	12.16	2.60, 56.85	0.002
High salt products ³ : 4 categories variable, 0 = none, 1 = low (≤1/wk), 2 = medium (>1-3/wk) & 4 = high (> 3/wk)					
Hindu	2.0 (0.2, 7.0)	0 = 143 (23.6) 1 = 124 (20.4) 2 = 115 (18.9) 3 = 225 (37.1)	Reference	-	-
Christian	3.0 (0.5, 7.0)	0 = 20 (18.0) 1 = 21 (18.9) 2 = 21 (18.9) 3 = 49 (44.1)	1.36	0.94, 1.96	0.11
Muslim	3.5 (0.5, 7.2)	0 = 10 (21.3) 1 = 6 (12.8) 2 = 7 (14.9) 3 = 24 (51.1)	1.59	0.91, 2.74	0.10
Jain	1.7 (1.2, 2.2)	0 = 0 (0.0) 1 = 2 (18.2) 2 = 8 (72.7) 3 = 1 (9.1)	1.11	0.38, 3.28	0.85
Visible fat ³ : 3 categories variable, 0 = low (<1/wk), 1 = medium (≥1- 4/wk) & 2 = high (>4/wk)					
Hindu	0.5 (0.0, 3.0)	0 = 322 (53.0) 1 =143 (23.6) 2 = 142 (23.4)	Reference	-	-
Christian	0.2 (0.0, 1.2)	0 = 69 (62.2) 1 = 31 (27.9) 2 = 11 (9.9)	0.61	0.41, 0.92	0.01*

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Participant religion (Hindu = 0, Christian = 1, Muslim = 2, Jain = 3)		
			β^1 / Odds ratio ^{2,3}	95% CI	p
Muslim	1.0 (0.0, 3.0)	0 = 20 (42.6) 1 = 19 (40.4) 2 = 8 (17.0)	0.18	0.68, 2.06	0.56
Jain	7.0 (0.5, 7.2)	0 = 3 (27.3) 1 = 0 (0.0) 2 = 8 (72.7)	7.28	2.09, 25.41	0.002

*Religion data missing data for 9 women.

*Red text indicates reference group.

¹ Food groups in white=continuous variables; ² Food groups shaded in grey=binary variables; ³ Food groups shaded in blue=ordinal categorical variables.

**Jains do not consume fish, egg, poultry and meat and hence were excluded from analysis of those food groups.

4.2.3. Family income

Table 4.3 shows that higher monthly income was associated with less frequent intake of milled cereals & products, cooked green leafy vegetables, added sugar, SSB & high sugar products, poultry and meat, and more frequent intakes of salads & raw vegetables, cooked vegetables, fresh fruit, dried fruit & and fruit juices, nuts & seeds, nutrient enriched beverage supplements and visible fat. For each SD increase in income, there was a 0.16 SD increase in frequency of intake of fresh fruit, dried fruit & fruit juices. For every one SD increase in monthly family income z-scores, the odds ratio for moving up one category of poultry consumption (from none to high) was 0.84 (95% CI: 0.73, 0.97).

Table 4.3: Regression analysis of income as a predictor of the weekly frequency of intake of food groups (n=637*)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2, 3})	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2, 3}	Predictor: Total monthly family income* in INR log transformed, z-standardised (SD)		
		β ¹ / Odds ratio ^{2, 3}	95% CI	p
Continuous variable, z-standardised; units = SD				
Milled cereals & products ¹	637 (100.0)	-0.11	-0.19, -0.03	0.006

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Total monthly family income* in INR log transformed, z-standardised (SD)		
		β ¹ / Odds ratio ^{2,3}	95% CI	p
Binary variable, 0 = none* & 1 = any				
Wholegrain cereals ²	0=88 (13.8) 1=549 (86.2)	0.87	0.69, 1.08	0.20
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Pulse & lentil preparations ¹	637 (100.0)	0.05	-0.03, 0.13	0.23
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Salads & raw vegetables ¹	637 (100.0)	0.11	0.03, 0.18	0.009
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Cooked vegetables ¹	637 (100.0)	0.13	0.05, 0.21	0.001
Binary variable, 0 = low ($\leq 1/\text{wk}$)* & 1 = high ($> 1/\text{wk}$)				
Potato containing dishes ²	0=154 (24.2) 1=483 (75.8)	-0.09	-0.18, -0.02	0.01
Binary variable, 0 = low ($< 1/\text{wk}$)* & high (1 = $\geq 1/\text{wk}$)				
Potato palya ²	0=341 (53.5) 1=296 (46.5)	1 1.09	- 0.93, 1.27	- 0.30
Continuous variable, square root transformed and z-standardised; units = SD				
Cooked Green leafy vegetables ¹	637 (100.0)	-0.09	-0.18, -0.02	0.01
Continuous variable, square root transformed and z-standardised; units = SD				
Fresh fruit, dried fruit & fruit juices ¹	637 (100.0)	0.16	0.08, 0.24	<0.001
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Nuts & seeds ¹	637 (100.0)	0.22	0.14, 0.30	<0.001
3 categories variable, 0 = none, 1 = low ($< 1/\text{wk}$) & 2 = high ($\geq 1 - 3/\text{wk}$)				
Fish & seafood ³	0=387 (60.8) 1=142 (22.2) 2=108 (17.0)	1.14	0.98, 1.33	0.10
3 categories variable, 0 = low($\leq 1/\text{wk}$), 1=medium($> 1 - 3/\text{wk}$) & 2=high ($> 3/\text{wk}$)				
Egg and egg preparations ³	0=252 (39.6) 1=200 (31.4) 2=185 (29.0)	0.91	0.79, 1.05	0.19
4 categories variable, 0 = none, 1 = low ($\leq 1/\text{wk}$), 2 = medium ($> 1-2/\text{wk}$) & 3 = high ($> 2/\text{wk}$)				
Poultry ³	0=161(25.3) 1=161(25.3) 2=150 (23.5) 3=165 (25.9)	0.84	0.73, 0.97	0.01
3 categories variable, 0 = none, 1 = low ($< 1/\text{wk}$) & 2 = medium ($\geq 1/\text{wk}$)				
Meat ³	0=306 (48.0) 1=165 (25.9) 2=166 (26.1)	0.79	0.68, 0.92	0.002
Continuous variable, square root transformed and z-standardised; units = SD				
Milk & dairy products ¹	637 (100.0)	0.01	-0.06, 0.09	0.64
Binary variable, 0 = none* & 1 = any				
Coffee ²	0=332 (52.1) 1=305 (47.9)	1 1.05	- 0.90, 1.23	- 0.51
Continuous variable, square root transformed and z-standardised; units = SD				
Fried & fast food ¹	637 (100.0)	0.03	-0.04, 0.11	0.39
Continuous variable, square root transformed and z-standardised; units = SD				

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Total monthly family income* in INR log transformed, z-standardised (SD)		
		β^1 / Odds ratio ^{2,3}	95% CI	p
Added sugar, SSB & high sugar products ¹	637 (100.0)	-0.08	-0.15, -0.002	0.04
Binary variable, 0 = none* & 1 = any				
Nutrient enriched beverage supplements ²	0=462 (72.5) 1=175 (27.5)	1 1.25	- 1.05, 1.49	- 0.01
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium ($> 1-3$ /wk) & 4 = high (> 3 /wk)				
High salt products ³	0=146 (22.9) 1=127 (19.9) 2=124 (19.5) 3=240 (37.7)	1.04	0.90, 1.19	0.60
3 categories variable, 0 = low (< 1 /wk), 1 = medium ($\geq 1-4$ /wk) & 2 = high (> 4 /wk)				
Visible fat ³	0=349 (54.8) 1=151 (23.7) 2=137 (21.5)	1.39	1.19, 1.63	<0.001

*Family income was not disclosed/not known by 148 women.
 *Red text indicates reference group.
¹ Food groups in white=continuous variables; ² Food groups shaded in grey=binary variables; ³ Food groups shaded in blue=ordinal categorical variables.

4.2.4. Standard of Living (SLI) score

Higher SLI score was associated with higher intakes of wholegrain cereals, pulse & lentil preparations, cooked vegetables, cooked green leafy vegetables, fresh fruit, dried fruit & fruit juices, milk & dairy products, coffee, nutrient enriched beverage supplements, and visible fat and lower egg and egg preparations (table 4.4, Appendix P, page 339). The weekly frequency of intake of fresh fruit, dried fruit and fruit juices was higher by 0.1 SD per increase in SLI score of 10 points. Nuts & seeds, salads & raw vegetables, fried & fast food, milled cereals and added sugar, SSB & high sugar products did not show an association with SLI score.

4.2.5. Participant's education level

More education was associated with lower intakes of milled cereals & products, added sugar, SSB & high sugar products, poultry and meat (table 4.5, Appendix P, page 340). For example, postgraduates had 0.30 SD lower frequency of intake of milled cereals & products than the reference group.

Intermediate and pre-university educated women consumed 0.31 SD less, graduates consumed 0.21 SD less and post graduates consumed 0.35 SD less frequency of intake of added sugar, SSB & high sugar products than women educated to high school or less.

More education was associated with higher intakes of nuts & seeds and nutrient enriched beverage supplements.

4.2.6. Urban vs. rural residence

Urban residence was used as the reference group. Rural women had more frequent intakes of milled cereals & products, wholegrain cereals, pulse & lentil preparations and cooked green leafy vegetables, than urban women. Urban women had more frequent intakes of nuts & seeds, nutrient enriched beverage supplements, fish & seafood and high salt products (table 4.6, Appendix P, page 345). Rural women had 0.13 SD higher intake of milled cereals & products than urban women. Urban women had more fish & seafood; the odds ratio for moving up to the next fish & seafood consumption group from none to high categories was 0.51 (95% CI: 0.37, 0.70) for rural women compared to urban women.

4.2.7. Nuclear vs. Joint family

Nuclear family was used as a reference group. Women from joint families had more frequent intakes of milled cereals & products, wholegrain cereals and cooked green leafy vegetables and pulse & lentil preparations than nuclear families (table 4.7, Appendix P, page 349). Women from nuclear families consumed more fish & seafood, egg and egg preparations and high salt products than women from joint families. Women from joint families had 0.20 SD higher intakes of cooked green leafy vegetables compared to women from nuclear families. The odds ratio for moving up a category of intake of high salt products from none to low groups was 0.72 (95% CI: 0.56, 0.93) for women from joint families compared to nuclear families.

4.2.8. Age

Older women had lower intakes of milled cereals & products and higher intakes of pulse & lentil preparations, salads & raw vegetables, cooked

vegetables, fresh fruit, dried fruit & fruit juices, nuts & seeds and added sugar, SSB & high sugar products (table 4.8, Appendix P, page 349). Also higher age was associated with marginally higher (odds ratio close to 1 but statistically significant) intakes of coffee, fish & seafood, egg and egg preparations, high salt products and visible fat. The intake of pulse & lentil preparations increased by 0.20 SD for every decade increase in age.

4.2.9. Body Mass Index (BMI)

A higher BMI was associated with less frequent intakes of milled cereals & products, fresh fruit, dried fruit & fruit juices and milk & dairy products (table 4.9, Appendix P, page 351). For example, a unit increase in BMI was associated with 0.02 SD decrease in intake of fresh fruit, dried fruit & fruit juices. A higher BMI was associated with a higher frequency of intake of coffee and lower frequency of intake of potato containing dishes.

4.2.10. Physical activity (weekly levels of light walking)

More active women had a higher frequency of intake of salads & raw vegetables, nuts & seeds, nutrient enriched beverage supplements and high salt products (table 4.10, Appendix P, page 353).

4.2.11. Family history of T2DM

Women with a family history of T2DM in a first degree relative, compared to women without, had a lower intake of nuts & seeds (table 4.11, Appendix P on page 354).

4.2.12. Polycystic ovarian syndrome (PCOS) and thyroid problems

Women with PCOS consumed less milled cereals & products, cooked greens, potato palya and poultry than women without PCOS diagnosis (table 4.12, Appendix P, page 356). They had higher intakes of pulse & lentil preparations, salads & raw vegetables, fresh fruit, dried fruit & fruit juices, nuts & seeds and nutrient enriched beverage supplements.

A history of thyroid problems (hypothyroidism) was associated with less frequent intakes of cooked green leafy vegetables, egg & egg preparations

and poultry (data not shown). Women with thyroid problems consumed nutrient enriched beverage supplements, high salt products and nuts & seeds more frequently, than women without thyroid problems.

4.2.13. Gravidity

Primigravid women were compared with multigravid women (table 4.13, Appendix P, page 358). Primigravid women had nutrient enriched beverage supplements more frequently than multigravid women. Multigravid women consumed more cooked vegetables, fresh fruit, dried fruit & fruit juices, nuts & seeds, egg & egg preparations and meat.

4.3. Discussion

Summary of findings: Diet represented by the food groups was associated differently with each population characteristic. Hospital type, religion, income, SLI and education were associated with the frequency of intake of many food groups. Area of residence, family type, age, BMI, PCOS diagnosis were associated with the frequency of intake of some food groups. Physical activity, family history of T2DM and gravidity were associated with differences in intake of a few food groups.

Religion: Religion is expected to be associated with specific food-based cultural differences among people in India (Mudambi & Rajagopal, 2001 & Maqsood, 2004). Expectedly in the study it was observed that Muslim women had the highest intakes of egg, poultry and meat. Muslims had the highest intake of potato palya, perhaps because they consume a lot of non-vegetarian foods that are expensive, which might be important culturally, and hence may prefer to consume potato, which is less expensive (INR 14 per kilogram) (Open daily, 2019). Another study looking at diet patterns among children in Mysore found that a diet pattern characterised by meat, fruits and snacks was associated with Muslims (Kehoe et al. 2014). This was similar to my study, in which Muslims had the highest meat intake and second highest intakes of fried food and fruits, after Jains.

Jains were a small group (1.4 percent) but were treated as a different category, because their dietary habits are different from other religions. The Jains have a rigorous form of spiritually motivated and completely vegetarian

diet (Chatterjee, 2000). Foods-grown-underground (garlic, potato, onions, sweet potatoes, carrots, radish, mushrooms and greens) are not consumed as they may contain soil microbes (Lodha, 1990). A typical Jain diet is abundant in wholegrain wheat pancakes (chapathis), broken wheat, fried snacks such as bhajias and home-made ghee (clarified butter). Expectedly in my study, Jain women were strict vegetarians and never consumed fish, meat, egg and poultry. They consumed pulse & lentil preparations, salads & raw vegetables, fresh fruit, dried fruit & fruit juices, fried & fast food, nutrient enriched beverage supplements, visible fat more frequently and potato and cooked greens less frequently, compared to women from other religions. Jain women had the most frequent intakes of nutrient enriched beverage supplements (12 times more than Hindus), that are expensive (INR 3000 per kilogram) and may be affordable by Jains, who are usually an affluent merchant community in India. Jain women also had the highest intakes of visible fat including ghee & butter (7 times more than Hindus), which is expected in their food-culture (Chatterjee, 2000). These expected religious differences were picked up well by the BANGLES FFQ.

There were also some unexpected religious differences in the intake of food groups. Hindus consumed milled and whole grain cereals, pulses, milk & dairy products more frequently than Christians and Muslims. Also Hindus consumed cooked greens more frequently and consumed fish, egg, poultry and meat less frequently than Christians and Muslims. Christians consumed salads & raw vegetables and fruit, less frequently, and had the most frequent intake of fish.

SES (income & SLI): Surprisingly, income in my study did not predict the intake of expensive commodities such as pulses, milk & dairy products, coffee and fish. However, SLI was better than income at predicting the intake of costly foods such as pulses, dairy, coffee, nutrient enriched beverage supplements and visible fat/ghee. Also, lower SLI, but not income, was associated with higher intakes of egg, which may be a cheaper source of protein than pulses in India today. Although traditional Indian diets have always relied on pulses as a daily food, intakes have reduced in the past decade, because of their increasing cost (Singh & Saxena, 2016). Pulses are expensive because of their reduced agricultural production since the 1950-60s compared with wheat and rice. Interestingly, income predicted sugar intake better than SLI, and in my

study higher sugar intake was not associated with lower SLI but was associated with lower income. Nevertheless, sugar intake is challenging to gauge among women of all social classes, and is known to be underreported in some studies (Bes-Rastrallo & Gonzalez, 2008). Both SLI and income are indicators of SES, although there were differences in how they predicted the intake of food groups. SLI is a broader SES assessment tool that assesses education, occupation and wealth indicators which could be shared in a family, while income is usually restricted to an individual (Cirto & Michael, 1995). Higher incomes might not necessarily translate into higher food expenditure and changes in food consumption patterns (Muhammad et al., 2017). The SLI index, being a composite SES measure is constructed using several variables of different socio-economic indicators of wealth and human capital, that might better reflect food expenditure patterns. Behavioural, social and cultural factors might play an important role in influencing food expenditure and consumption trends (Mozaffarian et al., 2018). For example, in a country like India, people with higher incomes might spend little on nutritious food and instead save up to buy gold or invest in fixed deposits. National food consumption data from the National Nutrition Monitoring Bureau (NNMB) and the National Family Health Surveys (NFHS) indicate that with an increase in SES, there is higher intake of vegetables, milk, pulses, non-vegetarian foods, edible fat and sugar and sweets. Also there is a changeover of cereals from wholegrains to refined cereals, with a reduction in amount, though still high compared to western standards (Vaz et al., 2005; WHO 1990). Similar to these findings, in my study higher income was associated with less frequent intakes of milled cereals and more frequent intakes of vegetables (cooked vegetables and greens), fruits, poultry, meat and visible fat. Also higher SLI was associated with more frequent intake of pulses, vegetables, fruits and visible fat. In contrast to the NNMB and NFHS data, wholegrain cereal intake improved with higher SLI in my study. This may be because of better health awareness that comes with increasing SES.

Education: Higher education was associated with reduced intake of milled cereals & products, meat and added sugar, SSB & high sugar products and higher intake of nuts & seeds, coffee and nutrient enriched beverage supplements. Many western studies have shown that educational attainment is an important determinant of healthy and unhealthy food choices women

make (Robinson et al., 2004). An Indian study that explored food consumption pattern and dietary diversity by SES using NFHS 4 data (2015-2016), found that education was the only component of SES that was strongly associated with consumption of all food groups (Agrawal et al., 2019). However, in my study these associations were restricted to some less healthy foods such as fried & fast food, or known healthy foods such as pulse & lentil preparations, salads & raw vegetables, cooked vegetables and greens, potato, fruits and fish. Surprisingly fish and egg, which are known to be healthy were not associated with education level, probably because a large section of women in the study were strict vegetarians. Expectedly, more education was associated with lower sugar intake which is generally known to be unhealthy. Additionally, more education was also associated with higher intake of nutrient enriched beverage supplements among women. This may be due to access to the internet and magazines that widely advertise and market these products as beneficial to health.

Family type: Women from joint families consumed more cooked greens and pulses than women from nuclear families. Joint families often have senior family members (mothers/mothers-in-law/grandmothers) who are better equipped to cook pulses that require time, cooking skills and traditional recipes. Similarly, older women also know how to incorporate greens regularly in their diets by appropriate cleaning and drying procedures.

Area of residence: Rural women consumed more milled and wholegrain cereals, pulses, and cooked greens than urban women. This could be due to better access to good-quality wholegrains, greens and pulses, cooking skills or available time, or the fact that rural women often live in large joint families with older family members supervising the cooking. Few studies in India have investigated detailed dietary differences between urban and rural areas.

Contrary to what I found, one study concluded that there were minimal urban-rural differences in dietary habits (Tripathy et al., 2016). Another report by Misra et al., 2011 suggested that rural and urban consumption-baskets have been quite similar since 1994, and suggested urbanisation of rural villages to be a cause for the lack of differences. Some studies in India have found that the intake of vegetables, dairy and sugar show an increasing trend from rural to migrant to urban groups (Bowen et al, 2011). Different findings could be due to populations with varied SES.

BMI: Higher BMI was associated with lower intakes of milled cereals and higher intakes of coffee. This may be due to underreporting of foods because of 'healthy or unhealthy' perceptions (Lilienthal & Lauren, 1995). But women with a higher BMI also reported lower frequent intake of fruits and dairy, which cannot be explained based on healthy perceptions. Similarly, BMI was not associated with other obviously 'unhealthy' foods such as sweets or fried & fast food. In contrast to my study, higher BMI was associated with higher frequency of dairy intake among Mumbai's slum dwelling women (Chopra et al., 2012). Also another study in urban South India found that higher BMI was positively associated with higher fruit and vegetable intake, in contrast to my findings (Radhika et al., 2008). These findings indicate that there may be a different socio-economic patterning of BMI that may influence food choices women make.

Age: Older women had higher pulse intake, probably because of the cooking skills of pre-soaking/germination/pressure-cooking required for pulse recipes, are acquired with practice and age. Older women had lower frequent intakes of milled cereals & products and higher frequent intake of salads & raw vegetables, cooked vegetables, fruits and nuts & seeds. This may be because of an increased awareness and motivation to take care of themselves that comes with age.

Gravidity: Multigravid women had a higher frequency of intakes of cooked vegetables, fresh fruit, dried fruit & fruit juices, nuts & seeds, egg & egg preparations and meat, than primigravid women. This was probably because multigravid women are usually older and due to their prior experience of pregnancy and childcare, may be more aware and wise in consuming healthy foods more frequently. Primigravid women consumed more nutrient enriched beverage supplements. These findings reflect that cultural-taboos and internet-trends may influence women to avoid or include some food groups.

PCOS: Women with a PCOS diagnosis had more frequent intakes of pulses, salads & raw vegetables, fruits, nuts & seeds and nutrient enriched beverage supplements, and less frequent intakes of milled cereals, potato and poultry. This could be because PCOS is a lifestyle disorder (Unfer et al., 2017) and often PCOS women, on diagnosis, consult a nutritionist or read health magazines (Lin et al., 2018). Interestingly women with thyroid problems

consumed more nutrient enriched beverage supplements, high salt products and lower green leafy vegetables and egg & egg preparations.

All the factors including SES, religion, area of residence, family type, age, physical activity, family history of T2DM, PCOS status and gravidity mentioned in the concept diagram drawn from the literature were associated with the exposure 'peri-conceptual diet' in different ways. They were considered potential confounders (factors related to both the exposure and the outcome) until their associations with GDM were studied, in the next chapter.

Chapter 5

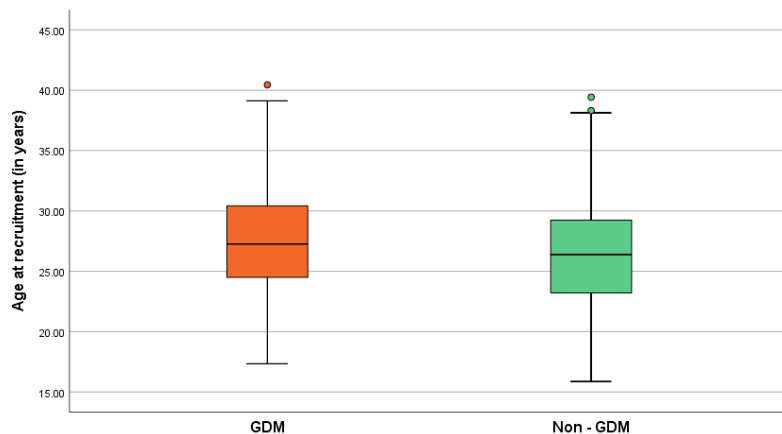
Population characteristics related to the development of the outcome - GDM

5.1. Background and aims of this chapter

This chapter aims to study associations between the outcome (development of GDM) and population characteristics known from previous literature to be associated with the risk of GDM. These include age, BMI, family history of T2DM, gravidity, PCOS, hypothyroidism, physical activity, SES indicators (income, standard of living index and education), religion, hospital type, urban/rural residence and nuclear/joint family type. The end of this chapter will finalise the data-driven selection of confounders that are associated with both the exposure 'diet' and outcome 'development of GDM'.

5.2. Univariate regression analysis of the population characteristics as predictors of GDM

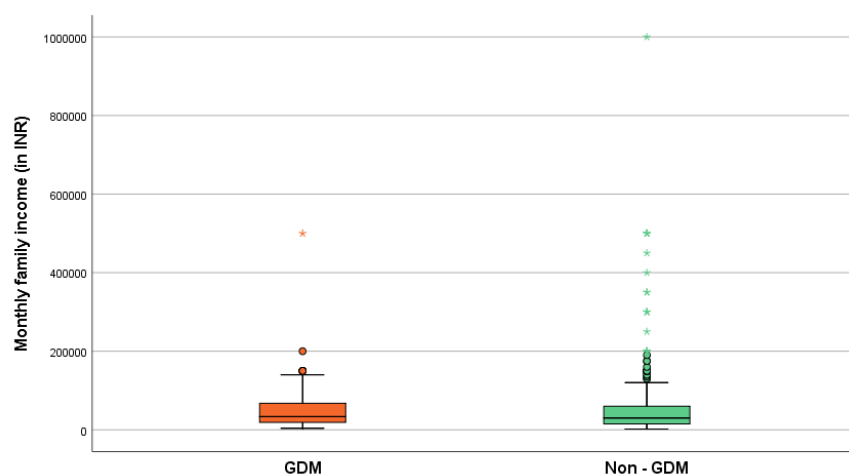
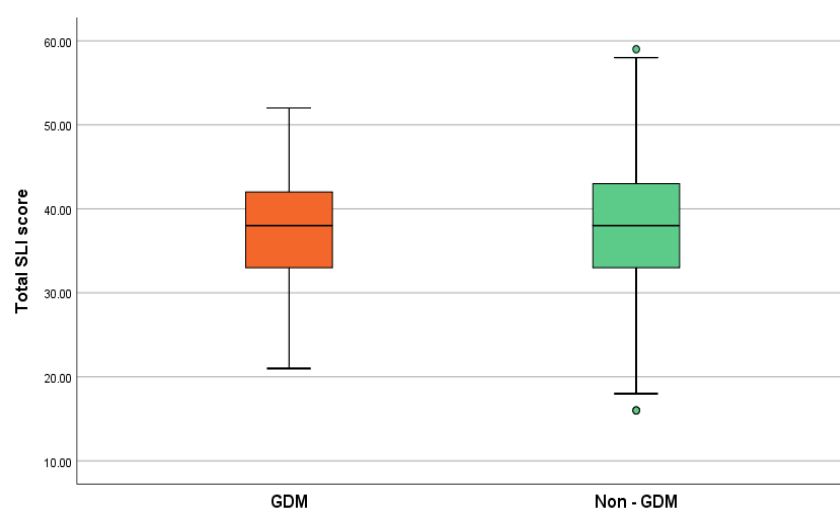
Table 5.1 shows that multigravid women had a 1.4 times higher GDM risk, compared to primigravid women ($p=0.04$). Women with PCOS and thyroid problems had a higher prevalence of GDM than those without PCOS and thyroid problems, but the difference was not statistically significant. Women who had a family history of T2DM were 1.6 times more likely to develop GDM, compared to women with no T2DM family history. GDM risk increased with increasing BMI (used as a continuous variable, $p<0.001$). The median BMI of the GDM group was higher, compared to the non-GDM group (25.1 v 22.1 kg/m²). Overweight and obese women were 2 times more likely to develop GDM, compared to women with normal BMI ($p=0.002$ for overweight and $p=0.01$ for obese women respectively). Older age was associated with a higher GDM risk ($p=0.005$, figure 5.1) when used as a continuous variable. The amount of time spent light walking per week was not associated with GDM risk in the study (table 5.1, page 152).

Figure 5.1: Boxplots of participant age at recruitment in GDM and non-GDM groups**Table 5.1: Univariate logistic regression analysis of the population characteristics as predictors of GDM (n=714*)**

Co-variates	Categories of comparison within each group	Total N (%)	GDM N (%)		OR	95% CI	p
			GDM N=157	Non-GDM N=557			
Gravidity * ¹	Primigravid	378 (52.9)	72 (19.0)	306 (81.0)	1	-	-
	Multigravid	336 (47.1)	85 (25.3)	251 (74.7)	1.44	1.01, 2.05	0.04
PCOS*	No	638 (89.5)	138 (21.6)	500 (78.4)	1	-	-
	Yes	75 (10.5)	18 (24.0)	57 (76.0)	1.14	0.65, 2.01	0.64
Hypothyroidism*	No	583 (81.9)	122 (20.9)	461 (79.1)	1	-	-
	Yes	129 (18.1)	34 (26.4)	95 (73.6)	1.35	0.87, 2.10	0.18
Family history of T2DM ²	No	481 (67.4)	93 (59.2)	388 (69.7)	1	-	-
	Yes	233 (32.6)	64 (40.8)	169 (30.3)	1.64	1.12, 2.40	0.01
BMI* (in Kg/m ²) as continuous Median (IQR):					1.11	1.07, 1.16	<0.001
GDM = 25.09 (22.1, 28.2)							
Non-GDM = 22.0 (19.9, 25.9)							
BMI categories	18.5-24.9	379 (53.1)	71 (18.7)	308 (81.3)	1	-	-

Co-variates	Categories of comparison within each group	Total N (%)	GDM N (%)	Non-GDM N (%)	OR	95% CI	p
	<18.5	67 (9.4)	6 (9.0)	61 (91.0)	0.42	0.17, 1.02	0.05
	25-29.9	186 (26.1)	57 (30.6)	129 (69.4)	1.91	1.27, 2.87	0.002
	>30	60 (8.4)	20 (33.3)	40 (66.7)	2.16	1.19, 3.93	0.01
Age (years) as continuous Mean (SD): GDM = 27.60 (4.62) Non-GDM = 26.49 (4.18)					1.06	1.02, 1.11	0.005
Age categories (years)	<22	102 (14.3)	19 (18.6)	83 (81.4)	1	-	-
	22-26	225 (31.5)	45 (20.0)	180 (80.0)	1.09	0.60, 1.98	0.77
	26-30	228 (31.9)	47 (20.6)	181 (79.4)	1.13	0.63, 2.05	0.68
	>30	159 (22.3)	46 (28.9)	113 (71.1)	1.78	0.97, 3.26	0.06
Time spent light walking (categories)							
<1 min/week		322 (45.1)	250 (45.1)	72 (46.5)	1	-	-
1-150 min/week		247 (34.6)	193 (34.8)	54 (34.8)	0.97	0.65, 1.45	0.88
>150 min/week		145 (20.3)	111 (20.0)	29 (18.7)	0.91	0.50, 1.47	0.69
Text in red indicates the reference group used in logistic regression models.							
¹ Gravidity means no of viable pregnancies. The term viable pregnancy means a pregnancy that lasts longer than 28 weeks.							
² History of T2DM among father, mother and siblings; 6 (0.8%) did not know family history of T2DM of T2DM.							
*Missing: PCOS = 1; Hypothyroid = 2 & BMI = 23.							

Table 5.2 shows that family income, standard of living Index (figures 5.2 and 5.3), and the participant's own education level did not show any associations with GDM risk.

Figure 5.2: Boxplots of monthly family income (in INR) in GDM and non-GDM groups**Figure 5.3: Boxplots of total SLI scores in GDM and non-GDM groups****Table 5.2: Logistic regression analysis of income, SLI and participant's education level as predictors of GDM (n=714)**

Co-variates	Categories of comparison within each group	Total N (%)	GDM status N (%)		OR	95% CI	p
			GDM	Non-GDM			
Monthly family income (in INR) ¹					1.04	0.86, 1.27	0.68
Median (IQR):							
GDM = 33500.0 (18000.0, 68750.0)							
Non-GDM = 30,000.0 (15,000, 60,000)							
Monthly family income (in INR) categories	< INR 25000	265 (37.1)	55 (20.8)	210 (79.2)	1	-	-

Co-variates	Categories of comparison within each group	Total N (%)	GDM status N (%)		OR	95% CI	p
			GDM	Non-GDM			
	INR 25000 to 50000	160 (22.4)	36 (22.5)	124 (77.5)	1.11	0.68, 1.78	0.67
	INR 50000 to 100000	99 (13.9)	26 (26.3)	73 (73.7)	1.36	0.80, 2.33	0.26
	INR >=100000	55 (7.7)	11 (20.0)	44 (80.0)	0.96	0.46, 1.97	0.90
	Not disclosed*	135 (18.9)	29 (21.5)	106 (78.5)	1.05	0.63, 1.73	0.87
Standard of Living Index Median (IQR): GDM = 38 (33, 42) Non - GDM = 38 (33, 43)					1.00	0.98, 1.03	0.87
SLI categories (quartiles)	Low	195 (27.3)	44 (25.5)	151 (27.1)	1	-	-
	Medium	160 (22.4)	38 (24.2)	122 (21.9)	1.10	0.68, 1.79	0.70
	Medium-high	168 (23.5)	35 (22.3)	133 (23.9)	1.18	0.71, 1.95	0.53
	High	191 (26.8)	40 (25.5)	151 (27.1)	0.99	0.60, 1.65	0.98
	High school and less	105 (14.7)	22 (21.0)	83 (79.0)	1	-	-
	Intermediate and Pre-university	123 (17.2)	24 (19.5)	99 (80.5)	0.92	0.48, 1.75	0.79
	Graduation	285 (39.9)	68 (23.9)	217 (76.1)	1.18	0.69, 2.04	0.55
Participant education ²	Post-graduation	201 (28.2)	43 (21.4)	158 (78.6)	1.03	0.58, 1.83	0.93

Text in **red** indicates the reference group used in logistic regression models.

¹ Monthly family income variable (N=566) is log transformed and Z-standardised in the logistic regression model; 148 women did report income.

² High school and less = minimum 8 years; Intermediate and Pre-University = minimum 12 years; Graduation = minimum 15 years; Post-graduation = minimum 18 years of education.

Table 5.3, page 156 shows that religion and hospital type did not show any association with GDM. Overall GDM prevalence was 16.0%, and 23.2% in women from Cloudnine and Baptist respectively. Women resident in rural areas were 0.6 times less likely to develop GDM compared to urban women (p=0.05). Women in joint families were 0.7 times less likely to develop GDM compared to women from nuclear families (p=0.05).

Table 5.3: Logistic regression analysis of religion, area of residence, family type and hospital type as predictors of GDM (n=714*)

Co-variates	Categories of comparison within each group	Total N (%)	GDM status N (%)		OR	95% CI	p
			GDM	Non-GDM			
Religion	Hindu	556 (77.9)	119 (21.4)	437 (78.6)	1	-	-
	Christian	101 (14.1)	26 (25.7)	75 (74.3)	1.27	0.78, 2.08	0.33
	Muslim	39 (5.5)	9 (23.1)	30 (76.9)	1.10	0.51, 2.38	0.81
	Jain	9 (1.3)	1 (11.1)	8 (88.9)	0.46	0.05, 3.71	0.47
Hospital type	Baptist	602 (84.4)	137 (22.8)	465 (77.2)	1	-	-
	Cloudnine	112 (15.6)	20 (17.9)	92 (82.1)	0.74	0.44, 1.24	0.25
Area of residence	Urban	487 (68.2)	118 (24.2)	369 (75.8)	1	-	-
	Rural	214 (30.0)	38 (17.8)	176 (82.2)	0.68	0.45, 1.02	0.05
	Not known	13 (1.8)	1 (7.7)	12 (92.3)	0.26	0.03, 2.03	0.20
Family type	Nuclear	557 (78.0)	94 (24.7)	287 (75.3)	1	-	-
	Joint	157 (22.0)	63 (18.9)	94 (24.7)	0.71	0.50, 1.02	0.05

Text in **red** indicates the reference group used in logistic regression models.

*Missing: Religion = 9; area of residence = 13

5.3. Multivariate regression analysis of the population characteristics as predictors of GDM development

We know from section 5.3 and table 5.1 that increased gravidity was positively associated with GDM. However, I wanted to explore if gravidity was associated with GDM through age, and therefore tested a multivariate model of gravidity and age as predictors of GDM. I observed that gravidity was associated with GDM in a univariate model but when age was added in a multivariate model, gravidity was no longer associated with GDM (table 5.4). In a multivariate model with all potential predictors of GDM, BMI was a powerful variable that attenuated all other associations, and was the only significant predictor of GDM. Table 5.5 shows the above described effect. A multivariate model to test predictors of GDM was not used since it was not my thesis question. My aim was to identify factors associated with GDM, to enable their adjustment in diet/ micronutrient-GDM models.

Table 5.4 : Univariate and multivariate logistic regression analysis of gravidity and age as predictors of GDM (n=714)

Univariate				Bivariate			
Model 1: Predictor = gravidity				Model 2: Predictors = gravidity, age			
	OR	95% CI	p		OR	95% CI	p
Gravidity ^a	1.44	1.01, 2.05	0.04	Gravidity	1.30	0.90, 1.87	0.16
Age	1.06	1.02, 1.11	0.005	Age	1.05	1.01, 1.09	0.01

^aGravidity: 0 = primigravid, 1 = multigravid

Table 5.5: Multivariate regression analysis of population characteristics as predictors of GDM

Population characteristics as predictors	Outcome: GDM (0 = no, 1 = yes)		
	OR	95% CI	p
Woman age (years)	1.00	0.94, 1.07	0.83
Gravidity (primigravida=0, multigravida=1)	1.02	0.64, 1.63	0.91
Family history of T2DM (0=no, 1=yes)	1.20	0.75, 1.90	0.43
PCOS status (0=no, 1 = yes)	0.84	0.40, 1.76	0.65
Hypothyroid status (0=no, 1 = yes)	1.05	0.61, 1.80	0.84
BMI	1.11	1.06, 1.17	<0.001
Weekly light walking			
No walking	1	-	-
<150 minutes per week	1.20	0.74, 1.95	0.45
>150 minutes per week	1.00	0.56, 1.78	0.98
Total SLI score	1.03	0.99, 1.06	0.10
Monthly family income (in INR)	1.01	0.73, 1.40	0.93
Participant's education level			
High school level of education	1	-	-
Intermediate & Pre-university	1.74	0.72, 4.21	0.21
Graduate	1.88	0.80, 4.42	0.14
Postgraduate	1.67	0.66, 4.23	0.27
Area of residence (0=urban, 1=rural)	0.91	0.53, 1.55	0.73
Family type (0=nuclear, 1= joint)	0.66	0.40, 1.08	0.10
Religion			
Hindu	1	-	-
Muslim	0.92	0.49, 1.71	0.79
Christian	0.91	0.28, 2.95	0.87
Jain	0.48	0.05, 4.34	0.51
Hospital type (Baptist=1, Cloudnine=2)	0.97	0.16, 5.66	0.98

5.4. Discussion

Summary: Higher BMI, age, gravidity and a family history of T2DM were positively associated with GDM risk in BANGLES. Rural residence and being in a joint family were associated with decreased GDM risk. In a multivariate model, BMI was the strongest and the only significant predictor of GDM risk. GDM was not related to income, SES, participant's education, PCOS, hypothyroidism, physical activity, religion or hospital type.

GDM prevalence: A fifth of women were diagnosed with GDM despite relatively few overweight, multigravid and older women. Less than half had a family history of T2DM, and only 10% had PCOS. Moreover 68% were educated to the level of graduation and post-graduation, median monthly income was INR 25,000 (approximately GBP 290); all of which certainly does not classify them as financially poor and most of them had a high SLI according to NFHS classification.

GDM prevalence was comparable to other studies in India. In the Parthenon study (n=785), an urban cohort at CSI Holdsworth Memorial hospital in Mysore (145 km. from Bangalore), GDM prevalence was 6.2% in 2005 (Hill et al., 2005) and has increased to an estimated 15.3% in the same hospital in recent times (estimated, no reference). Similar to Mysore, GDM prevalence has rapidly increased throughout India in the last two decades. Jali et al (2011) reported a GDM prevalence of 16% in urban Belgaum (n=325), In Tamil Nadu, prevalence varied from 3.8% to 23.3% (Mohan & Chandrakumar, 2016, Neelakandan & Sethu, 2014, Bhavadharini et al., 2016, and Seshiah et al., 2008). In 7 Indian cities (n=3674) it was 16.5% using the WHO 1999 diagnostic criteria (Seshiah et al., 2004). Prevalence also depends on the diagnostic criteria used. A systematic review including 64 studies reported prevalence rates of 19.19% using IADPSG and 10.13% using WHO 1999 criteria. A higher prevalence was reported with IADPSG, as they use a lower fasting plasma glucose cut off (Li et al., 2018). Currently, there is no universally directed national screening or diagnostic programme and different procedures are used throughout India (Veerasamy et al., 2015).

BMI: BMI was strongly associated with GDM, and attenuated all other associations linked to GDM in univariate models including those with age, gravidity, family history of T2DM, area of residence and family type in a

multivariate model. Increasing BMI is a well-known factor for GDM development. Associations between BMI and GDM have been reported in other Indian studies (Gopalakrishnan et al., 2015; Hill et al., 2005; Kulkarni et al., 2007, Madhavan et al., 2008; Ramachandran et al., 1997; Seshiah et al., 2008; Tripathi et al., 2012; Jali et al., 2011 & Zargar et al., 2004). A higher BMI generally means more adiposity. Adipose tissue (body fat) antagonizes the effect of insulin and leads to higher insulin resistance, high blood glucose, low grade chronic inflammation and β -cell dysfunction. This creates a metabolic milieu for GDM (Greenberg, 2006). Adiposity can cause insulin resistance by three main inter-related pathways: Firstly, greater adiposity leads to increased release of fatty acids from the body's adipose depots, which reduces skeletal muscle's capacity to dispose of fatty acids. As a result, a number of intermediate products of fatty acids such as diacylglycerol, fatty acyl-coenzyme A, and ceramides etc. accumulate in skeletal muscle, which impairs insulin signalling and contributes to insulin resistance. Secondly, increased flow of fatty acids to the liver via the portal vein leads to accumulation of fat in the liver, disrupting glucose and fat metabolism, and increasing blood glucose and triglyceride levels, which adds to insulin resistance. Thirdly, with greater adiposity there is low grade chronic inflammation in which inflammatory cells such as tumour necrosis factor- α (TNF- α), interleukin-6 (IL-6), monocyte chemoattractant protein-1 (MCP-1) and macrophages accumulate in the blood, and lead to insulin resistance by causing defects in insulin signalling. β -cell dysfunction is worsened by insulin resistance. Higher insulin leads to lesser glucose uptake from the blood stream resulting in high blood glucose levels, which overtaxes β -cells, eventually leading to β -cell 'exhaustion'. All these pathways set up a vicious cycle of high blood glucose, insulin resistance, and further β -cell dysfunction (Kahn & Flier, 2000; Ye et al., 2013; Choi & Cohen, 2017).

Body fat distribution is also a determinant of insulin resistance, independent of BMI. Individuals with normal BMI but more intra-abdominal fat (visceral adiposity) have more insulin resistance than those who have higher fat between skin and muscle wall (subcutaneous adiposity), or elsewhere like hips and thighs. Indians, even with normal BMI, often have high visceral or

central adiposity, which adds to insulin resistance (Chandalia et al., 1999; Ramachandran et al., 1997).

Age: Increasing age was clearly associated with GDM in my study, similar to many other studies (Hill et al., 2005, Seshiah et al., 2008, Tripathi et al., 2012, Arora et al., 2015 and Bhavadharini et al., 2016). The risk appears to increase continuously with age, with no particular 'threshold age' (Seshiah et al., 2008 and Rajput et al., 2013). Older women have reduced pancreatic beta cells (reduced with age) apart from a pregnancy's natural state of insulin resistance (Xiong et al., 2001). The attenuation of the association of age with GDM after adjusting for the woman's BMI suggests it is also partly attributable to the increase in adiposity with increasing age.

Gravidity: Indian studies have shown that gravidity >3 increases GDM risk (Seshiah et al., 2008 & Rajput et al., 2014). In BANGLES, gravidity was associated with GDM in a univariate model but not when age was added.

Family history of T2DM: Similar to my findings, many studies have reported an association with family history of T2DM (Hill et al., 2005, Seshiah et al., 2008, Tripathi et al., 2012, Rajput et al., 2014, Arora et al., 2015 and Bhavadharini et al., 2016) which may be explained by genes and inherited lifestyle components (Retnakaran et al., 2007). Again, the association was not significant after adjusting for BMI, suggesting that it is acting through genetic or shared lifestyle effects on adiposity.

PCOS and hypothyroidism: PCOS diagnosis was not related to GDM risk in my study, in spite of 10.5% of women having PCOS. PCOS has been reported as a risk factor for GDM due to pre-existing insulin resistance (Gupta et al., 2009, Wang et al., 2013, Joham et al., 2014, Qin et al., 2013 and Reyes-Munoz et al., 2012), although Kragelund et al., (2016) found no association. PCOS women may have been treated with metformin or lost weight to conceive, which may have reduced their GDM risk. Hypothyroidism was not associated with GDM, unlike a recent multiracial study (n=321) which reported a positive association (Rawal et al., 2018).

Physical activity: The lack of association between physical activity and GDM in BANGLES could be due to low variability in physical activity. Women largely believe that activity may harm their pregnancy, and were advised by elders to rest. Anjana et al., (2016) reported that only 10% of Indian pregnant

women met recommendations of 150 minutes of moderate physical activity per week. A case-control study involving 100 GDM women and 273 matched controls, found that pregnant women doing activities of ≥ 3000 MET-minutes/week pregnancy, had a 10-fold lower risk ($p < 0.001$), compared to less active women (Mishra & Kishore, 2018). Among 795 women, those with GDM were more sedentary than non-GDM women (86.2% vs. 61.2%) (Anjana et al., 2016).

Socioeconomic status: Unexpectedly, SES was not related to GDM in my study, although it included women from a range of SES. Possession of expensive commodities e.g. car, refrigerator, washing machine, air conditioner was not associated with GDM (data not shown). SES is challenging to measure and associations differ worldwide. Generally, lower SES, has been associated with higher GDM in western countries (Bo et al., 2002; Berkowitz et al., 1992) but Janghorbani et al., (2006) found no association. In India, a higher GDM risk has been associated with higher SES (Gopalakrishnan et al., 2015; Hill et al., 2005, Mohan & Chandrakumar, 2016 & Kragelund et al., 2016), for e.g. 16.8% for upper middle class women vs. 4.6% for lower middle class (Rajput et al., 2013). Women of higher SES when they conceive maybe - older, lead more sedentary lifestyles and have a higher pre-pregnancy BMI. Keshavarz et al., 2005 found a higher prevalence of GDM in lower SES women in Iran.

Women's education level was not associated with GDM in my study. Some studies have found higher GDM in more educated women compared to illiterate women and attribute the education association of GDM to age (Rajput et al., 2013). In contrast, Yang et al., 2002 found no association between education level and GDM in Chinese women. However most western studies have found an inverse association between women's education level and GDM. Education brings empowerment and awareness among women to make healthful lifestyle choices (Innes et al., 2002; Bo et al., 2002).

Area of residence: Rural women had a lower prevalence of GDM than urban women. Other Indian studies have found similar results (Zargar et al., 2004; Seshiah et al., 2008 and Bhavadharini et al., 2016). A systematic review of GDM in India by Li et al. (2018) reported 0.5 -13.9% prevalence among rural women in 9 studies, and 0.5-41.9% in 12 urban studies. Urban women may be at higher risk because of more sedentary lifestyles and less healthy diets.

This is supported by the finding that area of residence was not significant after adjusting for BMI.

Study strengths: We assessed glucose tolerance among 714 (91%) women at 24-28 weeks. 677 OGTTs were performed according to standard protocols with 75-gram anhydrous glucose administered after 8-10 hours fasting with precise gaps for postprandial 1 and 2-hour blood samples. We avoided OGTTs after 13 hours of fasting to reduce misdiagnosis. Further strengths and limitations are discussed in Chapter 10, section 10.2, pages 269 - 272).

5.5. Reviewing the concept diagram

Concept diagrams drawn from the literature and from the BANGLES data are shown in figures 5.4 and 5.5 respectively. Age, family history of T2DM, area of residence and family type were associated with both diet and GDM and were considered as 'data-driven' confounders. However, none of these associations with GDM risk were seen in a multivariate model with BMI, indicating that BMI was the strongest, independent and most statistically significant risk factor of GDM. Since BMI is strongly associated with both diet and GDM in the literature (figure 5.4) and my study (figure 5.5), I will investigate if BMI could be a mediator of associations between diet and GDM. Gravidity was associated with GDM through age (table 5.4) and was not included in further analyses.

Figure 5.4: Concept diagram exploring causal associations between diet and GDM, drawn from the literature

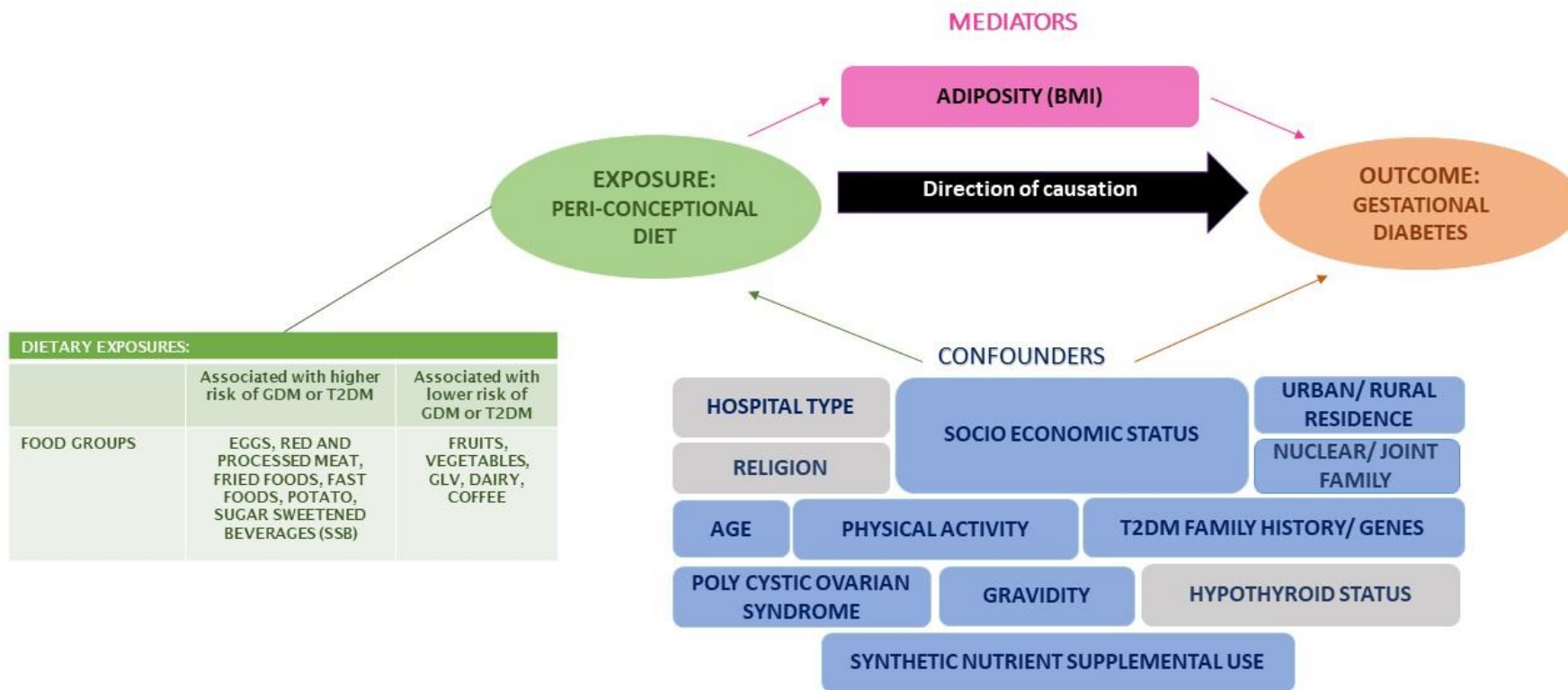
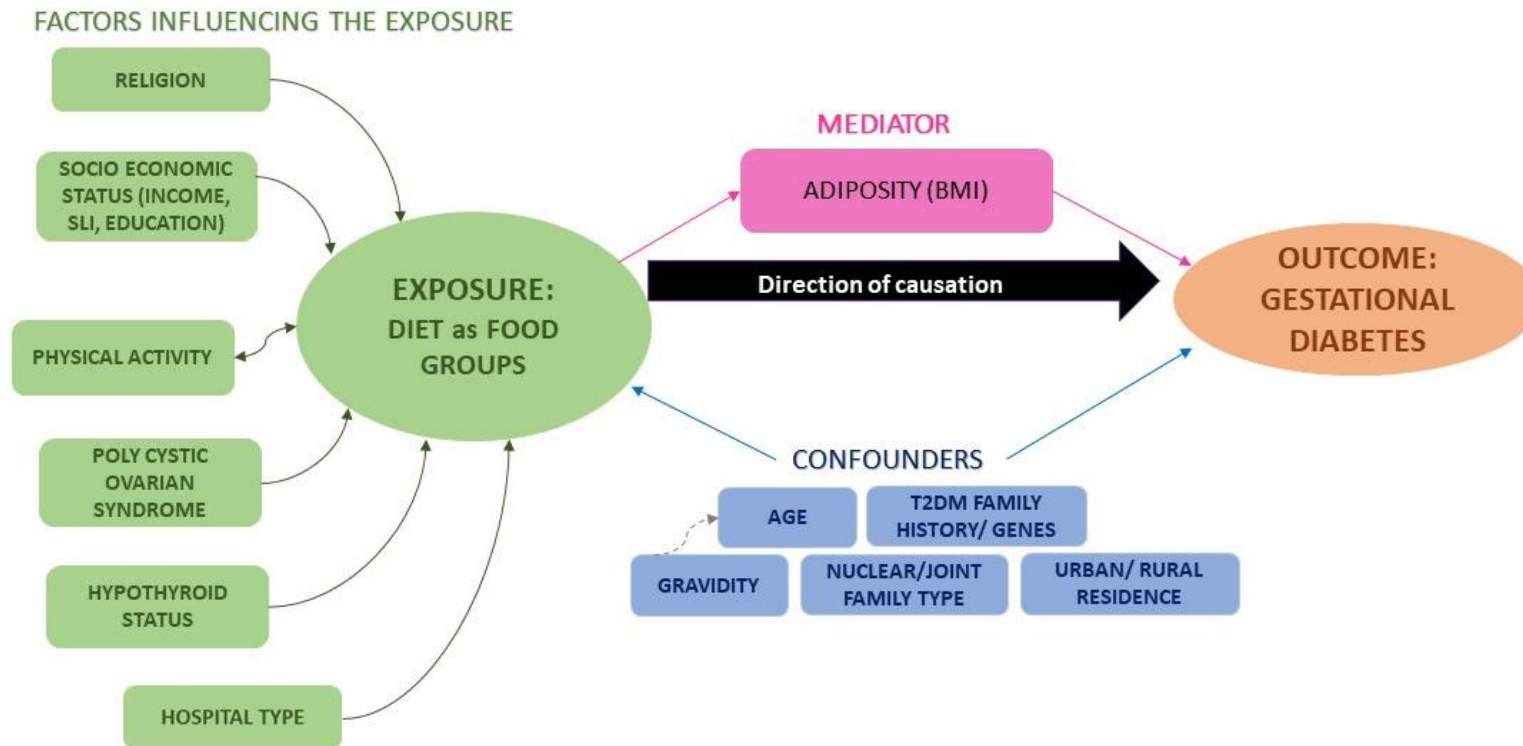


Figure 5.5: Concept diagram exploring causal associations between diet (food groups) and GDM, drawn from chapter 4 & 5 findings



Chapter 6

Association between women's peri-conceptual diet (food groups) and development of GDM

6.1. Background and aims of this chapter

Intakes of certain foods before and during pregnancy, such as egg and red and processed meat, have been associated with a higher GDM risk in the literature (1.5.3, pages 14 - 16). However, most studies assessing associations between food intake and GDM have been carried out in Western populations and there is sparse evidence from low and middle income country (LMIC) settings relevant to India. This chapter aims to answer my first thesis question: how peri-conceptual diet represented by food groups is associated with the development of GDM.

6.2. Association between peri-conceptual intake of food groups and GDM

I began this analysis by looking at the differences in frequency of food group intake between women who did and did not develop GDM, using non-parametric Mann-Whitney tests (table 6.1). To understand the extent of differences, I also performed regression analysis after transformation and z-standardisation of variables, with and without adjustment for confounders and BMI (tables 6.2 & 6.3).

6.2.1. Median differences in intake of food groups between women who did and did not develop GDM

Women who developed GDM reported a lower frequency of intake of fried and fast foods (5.7 v 7.0 per week, $p=0.005$, table 6.1). There were no significant differences between GDM and non-GDM women in reported intakes of any of the other foods associated with an increased risk of GDM/T2DM in the literature described in chapter 1 (shaded amber in the table). Women who developed GDM had slightly lower intakes of whole grain cereals, cooked

vegetables, green leafy vegetables and fresh fruit and fruit juices (foods that have been associated with a lower risk of GDM/T2DM in the literature, shaded green in the table) but these differences were not statistically significant (table 6.1).

Table 6.1: Median weekly frequency of peri-conceptional intake of food groups among women who did and did not develop GDM (n=714)

Weekly frequency of food group intake	GDM = 157	Non-GDM = 557	p
Milled cereals & products	36.25 (29.75, 44.50)	38.25 (31.00, 45.5)	0.20
Whole grain cereals	3.25 (0.25, 7.62)	4.50 (1.00, 7.75)	0.17
Pulse and lentil preparations	4.00 (2.37, 6.00)	4.00 (2.50, 7.50)	0.19
Salads & raw vegetables	3.00 (1.25, 7.00)	3.00 (1.25, 6.00)	0.63
Cooked vegetables	9.00 (6.25, 13.37)	9.50 (6.25, 14.00)	0.64
Potato containing dishes	2.00 (1.00, 3.62)	2.25 (1.25, 3.75)	0.42
Potato palya	0.50 (0.25, 1.00)	0.75 (0.25, 1.00)	0.52
Cooked green leafy vegetables	3.00 (2.00, 4.00)	3.00 (2.00, 5.00)	0.19
Fresh fruit, dried fruit and fruit juices	19.00 (13.25, 29.25)	19.75 (11.75, 31.12)	0.59
Fish & seafood	0.00 (0.00, 0.50)	0.00 (0.00, 0.50)	0.13
Egg & egg preparations	1.75 (0.25, 3.50)	1.75 (0.50, 3.50)	0.95
Poultry	1.25 (0.37, 2.25)	1.25 (0.25, 2.25)	0.46
Meat	0.25 (0.00, 1.00)	0.25 (0.00, 1.00)	0.22
Nuts & seeds	4.00 (2.00, 9.00)	4.50 (2.00, 10.00)	0.14
Milk & dairy products	21.00 (14.00, 28.00)	18.50 (12.75, 26.00)	0.15
Coffee	1.00 (0.00, 7.00)	0.00 (0.00, 7.00)	0.08
Fried & fast food	5.75 (3.00, 9.62)	7.00 (3.75, 11.50)	0.005
Added sugar, SSB and high sugar products	20.59 (12.62, 28.12)	20.00 (12.50, 28.25)	0.71
Nutrient enriched beverage supplements ^a	0.00 (0.00, 0.00)	0.00 (0.00, 1.00)	0.14
High salt products	1.25 (0.25, 7.00)	2.00 (0.50, 7.00)	0.26
Visible fat	0.25 (0.00, 3.00)	0.50 (0.00, 3.00)	0.37
Food groups coloured in green have been associated with a lower GDM / T2DM risk in the literature; Food groups coloured in amber have been associated with a higher GDM / T2DM risk in the literature.			
^a Nutrient enriched powders were computed from FFQ data and used as a continuous variable.			

6.2.2. Univariate and multivariate logistic regression analysis of food groups as predictors of GDM

Results of assessing the same data using regression are shown in tables 6.2 and 6.3, including univariate and multivariate models adjusted for confounders using ‘data-driven’ and ‘*a priori*’ models. In the univariate models, any intake of wholegrain cereals and coffee, compared to none, and moderate

egg consumption (>1-3 times/week compared to <1 time/week) were associated with lower GDM risk. In the multivariate models using data-driven confounders (table 6.2), women who consumed wholegrain cereals had a 0.6 times lower GDM risk than those who did not ($p=0.03$). Expressing this in terms of a percentage - women who consumed wholegrain cereals compared to those who did not, were 40 percent less likely to develop GDM. A higher frequency of intake of nuts and seeds was associated with a lower risk of GDM ($p=0.02$). Women who ate moderate amounts of the egg (>1-3 times/week) had a 0.5 times lower risk of GDM ($p=0.01$), compared to those who ate them $\leq$ once a week. A higher frequency of intake of fried and fast food was also associated with a lower GDM risk ($p=0.03$). Adding BMI to the model did not alter these findings for most food groups, indicating that these associations are unlikely to be mediated by BMI. The rest of the food groups did not show any association with GDM.

Table 6.3 shows that multivariate regression models adjusted for confounders selected *a priori* on the basis of previous literature, with and without BMI, did not change the above findings except for pulses. Higher intakes of pulses were significantly associated with lower GDM risk.

None of the above associations remained significant after applying the Benjamini-Hochberg correction for multiple tests, in either the data driven or *a priori* models (tables 6.2 and 6.3).

Table 6.2. Univariate and multivariate logistic regression analysis of weekly frequency of peri-conceptional intake of food groups as predictors of GDM adjusted for confounders selected by the data-driven method (without BMI, n=701 & with BMI, n=678)

Predictors	Categories of comparison within each predictor	Outcome = GDM (0 = no, 1 = yes)									p*
		Univariate model ¹			Multivariate model ²						
					Models without BMI			Models with BMI			
		OR	95% CI	p	OR	95% CI	p	OR	95% CI	p	
Milled cereals and products ¹	-	0.87	0.72, 1.04	0.14	0.91	0.76, 1.09	0.31	0.95	0.78, 1.15	0.58	NS
Wholegrain cereals ²	None	1	-	-	1	-	-	1	-	-	-
	Any	0.56	0.34, 0.91	0.01	0.58	0.35, 0.95	0.03	0.56	0.34, 0.94	0.02	NS
Pulse and lentil preparations ¹	-	0.86	0.72, 1.04	0.12	0.86	0.72, 1.04	0.11	0.85	0.70, 1.02	0.08	-
Salads & raw vegetables ¹	-	1.05	0.88, 1.26	0.57	1.05	0.88, 1.26	0.59	1.05	0.87, 1.27	0.60	-
Cooked vegetables ¹	-	0.93	0.77, 1.12	0.46	0.91	0.75, 1.10	0.33	0.88	0.72, 1.07	0.19	-
Potato containing dishes ²	Low (≤1/wk)	1	-	-	1	-	-	1	-	-	-
	High (>1/wk)	0.80	0.53, 1.20	0.28	0.80	0.53, 1.21	0.30	0.86	0.56, 1.33	0.50	NS
Potato palya (potato only dish) ²	Low (<1/wk)	1	-	-	1	-	-	1	-	-	-
	High (≥1/wk)	0.96	0.67, 1.37	0.84	0.95	0.66, 1.36	0.77	0.99	0.68, 1.44	0.98	NS
Cooked green leafy vegetables ¹	-	0.92	0.77, 1.10	0.38	0.95	0.79, 1.14	0.60	0.97	0.81, 1.17	0.77	NS
Fresh fruit, dried fruit, fruit juices ¹	-	0.94	0.79, 1.13	0.53	0.91	0.76, 1.09	0.33	0.98	0.81, 1.18	0.79	NS
Nuts & seeds ¹	-	0.85	0.71, 1.02	0.09	0.80	0.67, 0.97	0.02	0.83	0.69, 1.01	0.06	NS
Fish & seafood ³	None	1	-	-	1	-	-	1	-	-	-
	Low (<1/wk)	1.30	0.85, 2.00	0.22	1.29	0.83, 1.99	0.26	1.15	0.73, 1.82	0.53	NS
	High (≥1-3/wk)	1.28	0.80, 2.07	0.29	1.05	0.64, 1.71	0.85	1.07	0.64, 1.78	0.80	NS
Egg & egg preparations ³	Low (≤1/wk)	1	-	-	1	-	-	1	-	-	-
	Medium (>1-3/wk)	0.60	0.39, 0.90	0.02	0.58	0.37, 0.90	0.01	0.57	0.36, 0.90	0.01	NS
Poultry ³	High (>3/wk)	0.92	0.60, 1.40	0.70	0.86	0.55, 1.34	0.49	0.86	0.55, 1.34	0.49	NS
	None	1	-	-	1	-	-	1	-	-	-
	Low (≤1/ wk)	1.17	0.70, 1.97	0.53	1.40	0.81, 2.36	0.22	1.32	0.77, 2.28	0.31	NS
	Medium (>1-2/wk)	1.19	0.71, 2.02	0.49	1.41	0.83, 2.41	0.20	1.30	0.75, 2.25	0.34	NS
	High (>2/wk)	1.26	0.76, 2.09	0.36	1.29	0.77, 2.15	0.34	1.26	0.75, 2.13	0.38	NS

Predictors	Categories of comparison within each predictor	Outcome = GDM (0 = no, 1 = yes)									p*
		Univariate model ¹			Multivariate model ²						
		OR	95% CI	p	Models without BMI			Models with BMI			
OR	95% CI				p	OR	95% CI	p			
Meat ³	None	1	-	-	1	-	-	1	-	-	-
	Low (<1/wk)	1.21	0.79, 1.87	0.37	1.14	0.73, 1.77	0.57	1.02	0.64, 1.60	0.94	NS
	Medium (≥1/wk)	1.15	0.75, 1.75	0.52	1.13	0.73, 1.74	0.57	1.11	0.71, 1.72	0.65	NS
Milk & dairy products ¹	-	1.11	0.93, 1.33	0.23	1.10	0.93, 1.33	0.26	1.13	0.94, 1.36	0.21	NS
Coffee ²	None	1	-	-	1	-	-	1	-	-	-
	Any	1.44	1.01, 2.06	0.04	1.40	0.98, 2.01	0.06	1.35	0.93, 1.96	0.12	NS
Fried & fast food ¹	-	0.77	0.64, 0.92	0.06	0.78	0.65, 0.94	0.01	0.82	0.67, 0.99	0.04	NS
Added sugar, SSB and high sugar products ¹	-	1.03	0.86, 1.23	0.71	1.02	0.85, 1.23	0.80	1.02	0.85, 1.23	0.81	NS
Nutrient enriched beverage supplements ²	None	1	-	-	1	-	-	1	-	-	-
	Any	0.74	0.50, 1.09	0.13	0.72	0.48, 1.09	0.12	0.78	0.50, 1.18	0.22	NS
High salt products ³	None	1	-	-	1	-	-	1	-	-	-
	Low (≤1/wk)	1.05	0.61, 1.80	0.85	0.93	0.53, 1.61	0.79	1.02	0.58, 1.80	0.94	NS
	Medium (>1-3/wk)	1.03	0.60, 1.76	0.90	0.90	0.52, 1.58	0.72	0.90	0.51, 1.59	0.71	NS
	High (>3/wk)	0.83	0.51, 1.34	0.45	0.74	0.45, 1.20	0.22	0.79	0.47, 1.30	0.34	NS
Visible fat ³	Low (<1/wk)	1	-	-	1	-	-	1	-	-	-
	Medium (≥1-4/wk)	0.74	0.47, 1.15	0.18	0.67	0.43, 1.06	0.08	0.71	0.45, 1.12	0.14	NS
	High (>4/wk)	0.84	0.53, 1.32	0.46	0.81	0.51, 1.28	0.36	0.91	0.57, 1.47	0.71	NS

Each food group was analysed in a separate regression analysis with and without BMI. All multivariate models were adjusted for the woman's age, area of residence (urban/rural), family type (nuclear/joint) and family history of T2DM (no/yes).

Text in red indicates the reference group used in logistic regression models.

p* after Benjamini-Hochberg correction, NS means not significant.

¹ Continuous, transformed, z-standardised food group variables used in logistic regression analysis.

^{2,3} Categorical food group variables used in logistic regression analysis (grey boxes).

*Missing data: area of residence=13, BMI=23

Table 6.3. Multivariate logistic regression analysis of weekly frequency of peri-conceptional intake of food groups as predictors of GDM adjusted for *a priori* confounders from previous literature (without BMI, n=700 & with BMI, n=677)

Predictors	Categories of comparison within each predictor	Outcome = GDM (0 = no, 1 = yes)						p*
		Multivariate model ³						
		Models without BMI			Models with BMI			
		OR	95% CI	p	OR	95% CI	p	
Milled cereals and products ¹	-	0.86	0.71, 1.04	0.13	0.91	0.74, 1.11	0.35	NS
Wholegrain cereals ²	None	1	-	-	1	-	-	NS
	Any	0.58	0.34, 0.97	0.03	0.56	0.33, 0.97	0.03	NS
Pulse and lentil preparations ¹	-	0.81	0.66, 0.98	0.03	0.79	0.65, 0.97	0.02	NS
Salads & raw vegetables ¹	-	0.99	0.82, 1.20	0.95	1.00	0.82, 1.22	0.95	NS
Cooked vegetables ¹	-	0.83	0.68, 1.02	0.08	0.82	0.66, 1.01	0.06	NS
Potato containing dishes ²	Low (≤1/wk)	1	-	-	1	-	-	NS
	High (>1/wk)	0.72	0.47, 1.12	0.15	0.74	0.47, 1.16	0.19	NS
Potato palya (potato only dish) ²	Low (<1/wk)	1	-	-	1	-	-	NS
	High (≥1/wk)	0.81	0.55, 1.18	0.28	0.83	0.56, 1.23	0.36	NS
Cooked green leafy vegetables ¹	-	0.72	0.47, 1.12	0.15	0.74	0.47, 1.16	0.19	NS
Fresh fruit, dried fruit, fruit juices ¹	-	0.90	0.74, 1.09	0.30	0.97	0.80, 1.19	0.82	NS
Nuts & seeds ¹	-	0.77	0.63, 0.94	0.01	0.81	0.66, 0.99	0.04	NS
Fish & seafood ³	None	1	-	-	1	-	-	NS
	Low (<1/wk)	1.11	0.70, 1.78	0.63	1.05	0.66, 1.70	0.82	NS
	High (≥1-3/wk)	1.00	0.60, 1.67	0.99	1.04	0.61, 1.76	0.88	NS
Egg & egg preparations ³	Low (≤1/wk)	1	-	-	1	-	-	NS
	Medium (>1-3/wk)	0.54	0.34, 0.86	0.01	0.56	0.35, 0.90	0.01	NS
Poultry ³	High (>3/wk)	0.67	0.42, 1.07	0.10	0.66	0.41, 1.08	0.10	NS
	None	1	-	-	1	-	-	NS
	Low (≤1/ wk)	1.36	0.77, 2.39	0.28	1.27	0.71, 2.27	0.41	NS
	Medium (>1-2/wk)	1.15	0.65, 2.04	0.61	1.09	0.61, 1.95	0.75	NS
	High (>2/wk)	1.07	0.62, 1.84	0.79	1.08	0.62, 1.88	0.76	NS

Predictors	Categories of comparison within each predictor	Outcome = GDM (0 = no, 1 = yes)						p*
		Multivariate model ³						
		Models without BMI			Models with BMI			
		OR	95% CI	p	OR	95% CI	p	
Meat ³	None	1	-	-	1	-	-	NS
	Low (<1/wk)	1.09	0.69, 1.73	0.70	0.94	0.59, 1.50	0.82	NS
	Medium (≥1/wk)	0.94	0.59, 1.50	0.82	0.96	0.59, 1.54	0.87	NS
Milk & dairy products ¹	-	1.10	0.91, 1.33	0.29	1.11	0.92, 1.35	0.26	NS
Coffee ²	None	1	-	-	1	-	-	NS
	Any	1.51	1.03, 1.21	0.03	1.44	0.97, 2.13	0.06	NS
Fried & fast food ¹	-	0.72	0.59, 0.89	0.002	0.75	0.60, 0.92	0.008	NS
Added sugar, SSB and high sugar products ¹	-	1.02	0.84, 1.23	0.83	1.02	0.84, 1.24	0.82	NS
Nutrient enriched beverage supplements ²	None	1	-	-	1	-	-	NS
	Any	0.58	0.20, 1.67	0.31	0.62	0.21, 1.78	0.37	NS
High salt products ³	None	1	-	-	1	-	-	NS
	Low (≤1/wk)	1.01	0.56, 1.81	0.96	1.09	0.60, 1.98	0.77	NS
	Medium (>1-3/wk)	0.85	0.47, 1.53	0.59	0.86	0.47, 1.56	0.62	NS
	High (>3/wk)	0.70	0.42, 1.19	0.19	0.75	0.44, 1.29	0.30	NS
Visible fat ³	Low (<1/wk)	1	-	-	1	-	-	NS
	Medium (≥1-4/wk)	0.68	0.43, 1.10	0.11	0.70	0.43, 1.13	0.15	NS
	High (>4/wk)	0.74	0.45, 1.21	0.24	0.81	0.49, 1.34	0.42	NS

Each food group was analysed in a separate regression analysis with and without BMI. All multivariate models were adjusted for the woman's age, gravidity, PCOS status (no/yes), area of residence (urban/rural), family type (nuclear/ joint), family history of T2DM (no/yes), use of nutrient supplements (Calcium-vitamin D, B12, iron, folic acid and energy-protein), physical activity (weekly light walking) and SES measures (SLI score, education & occupation levels).

Text in red indicates the reference group.

p* after Benjamini-Hochberg correction, NS means not significant.

¹ Continuous, transformed, z-standardised food group variables used in logistic regression analysis.

^{2,3} Categorical food group variables used in logistic regression analysis (grey boxes).

*Missing data: area of residence=13, PCOS=1, BMI=23

6.3. Discussion

Summary of findings: Higher intakes of wholegrain cereals, nuts and seeds, egg and egg preparations and fried and fast food were associated with a lower GDM risk, after adjusting for age, area of residence, family type and family history of T2DM (confounders). These findings did not alter when BMI was added to the models suggesting these associations are not mediated by effects of these foods on BMI. Additionally, pulse and lentil preparations were associated with a lower GDM risk after adjusting for confounders and BMI in the *a priori* model, which included a wider range of confounders. Findings were consistent across *a priori* and data-driven models. None of these associations remained significant after Benjamini-Hochberg multiple testing corrections. Below is a detailed discussion of the findings for food groups based on my results presented in section 6.2.

There were no significant associations between food groups and GDM risk after multiple testing correction. This contrasts with the results of previous prospective studies, mainly from western countries, which have shown that higher intakes of refined cereals, eggs, meat, fried and fast foods and sugar are associated with a higher GDM risk, while wholegrains, salads, fresh fruit and vegetables appear protective. Before making adjustments to allow for the number of tests carried out, there were traditionally significant ($p < 0.05$) inverse associations of the frequency of intake of wholegrain cereals, pulses, nuts and seeds and the risk of GDM. Although, the multiple testing corrected results indicate that these may be chance findings, they are consistent with the previous literature, and, taking a balanced view, add support for the advice to women to include these micronutrient-rich foods in a healthy balanced diet. The plausibility of these associations is discussed below. Surprising results, completely different from the findings in previous studies, were inverse associations between intake of egg, and fried and fast food, with GDM risk. Again, these were no longer statistically significant after multiple testing corrections, and may be chance findings, or they may point to associations particular to Indian diets/diet patterns, also discussed below. There was no evidence for some associations seen in western studies, notably an association of greater GDM with higher meat intakes and lower intakes of fresh fruits and vegetables. One explanation could be a lack of variation of

intakes, which could reduce the power to detect associations. This could be true for meat, which is either not eaten at all or eaten in relatively small quantities. The meat consumption in India is rising with rising incomes and urbanisation but still well below the global average (Sharma et al., 2020). Vegetables, form a major part of almost all Indian diets but cooking methods tend to be longer in Indian, compared to western cooking which may reduce the micronutrients and fibre benefits of vegetables that may control blood glucose. The median weekly frequency of intake of cooked vegetables was 9.5 and cooked greens was 3, corresponding to approximately 86 grams per day, which is lesser than the WHO recommendation of 400 grams per day (WHO, 2003). Although, women consumed enough fruits there may have been less diversity, with more focus on fruits like banana.

Wholegrain cereals: this food group included ragi, chapathi and wholegrain or unpolished rice. More than 40% of the women consumed finger millet (ragi) as their staple cereal in the form of ragi ball at least once a day in my study. Ragi compositionwise contains between 15-20% of dietary fibre (Devi et al., 2014a). Millets are a rich source of minerals, polyphenols and vitamins, which are available because finger millet flour is produced by keeping the cereal grain's outercoat intact. Wholegrain cereals can contain soluble or insoluble fibre. While finger millets (ragi), whole grain wheat and rice contain insoluble fibre in the form of cellulose, hemi cellulose and lignin, oats contain soluble fibre such as beta glucan and arabinoxxyglycan (Devi et al., 2014a). Insoluble fibre from wholegrain cereals leads to higher satiety and satiation and therefore regulates food intake. Additionally, wholegrain cereals may delay gastric emptying rate, which slows down digestion and glucose absorption and reduces plasma insulin levels (Chandalia et al., 2000). There is strong evidence that links intake of wholegrain cereals with lower risk of GDM and T2DM (Chandalia et al, 2000; Zhang et al., 2006b and Neunschwander et al., 2019). The Nurses' Health Study-II, showed an association between higher pre-pregnancy intake of cereal and fruit fibre and lower GDM risk (Zhang et al., 2006b). A meta-analysis found that, a 30-gram increase of wholegrains per day (i.e. an extra serving daily) could offer a substantial T2DM risk reduction among adults (adjusted hazard ratio: 0.87, 95% CI 0.82, 0.93) (Neunschwander and colleagues et al., 2019).

Nuts and seeds: Nuts and seeds may help glucose control and appetite suppression as they contain Monounsaturated fatty acids (MUFA), that are known to control post meal glucose values from rising rapidly, and the fibre and magnesium-content of nuts may improve insulin sensitivity (Schwingshackl et al, 2015). Fibre and polyphenols in nuts and seeds may also alter gut microbiota and the production of short chain fatty acids (SCFAs) like acetate, propionate and butyrate. These SCFAs can confer cardio-metabolic benefits by lowering fasting blood glucose and cholesterol (Kim et al., 2017).

The St. Carlos GDM prevention trial among 1000 Spanish normal weight women consisted of an intervention started in early pregnancy, where advocating a Mediterranean diet and daily supplementation with 40 ml extra virgin oil and 30 grams of pistachios reduced GDM incidence at 6 months (RR = 0.73, 95% CI 0.56, 0.95), compared with the control group with standard diet and limited fat intake (Assaf-Balut et al., 2017). This finding could be due to other healthy components of the Mediterranean diet such as whole grain cereals, legumes, fruits and vegetables, which were advocated but not provided. Greater than 3 weekly servings of nuts was associated with a lower GDM risk in Spain (Ruiz-Gracia et al., 2016), and the NHS II study in the US found that intake of vegetable protein (mostly from nuts) was associated with a lower GDM risk (Bao et al., 2013) details of these studies in Chapter 1, table 1.4, page 17).

Egg: The Alpha and Omega studies found that women in the USA (n=3158) with a pre-pregnancy egg intake of ≥ 7 times/ week had a higher GDM risk than those who consumed egg less than 7 times per week (Alpha: OR 2.65, 95% CI 1.48, 4.72; Omega: RR 1.77, 95% CI, 1.19, 2.63) (Qiu et al., 2011a). Similar findings have not been replicated in any other studies.

In my study there was a trend towards women consuming egg 1-3 times per week having a lower GDM risk. Possible protective mechanisms include: i) The phospholipids in egg have been shown to increase high-density lipoprotein (HDL) levels, commonly termed 'good cholesterol', which have an important role in maintaining normal blood glucose levels (Sunwoo et al., 2015). ii) Polyphenols in egg, namely lutein and zeaxanthin are known to possess anti-oxidative and anti-inflammatory properties (Ciccione et al., 2013) and iii) egg white protein may increase insulin sensitivity (Jahandideh et al., 2017).

There may be possible reasons for different findings in India and the United states in relation to egg consumption and GDM risk. Firstly, egg intake in both India and the USA may be associated with more meat intake, and the per capita meat consumption in India is 5 kgs. per year (OECD-FAO, 2014). This is much less than the annual per capita meat consumption of greater than 120 kgs. in the USA (OECD-FAO, 2014), where higher pre-pregnancy intake of meat has been associated with higher GDM risk (Bao et al., 2013). Secondly, there may be a difference in the type of egg consumed. In India, 'nati eggs' (local regional term for organic country eggs) may be consumed, which may be healthier than large-scale, farm produced eggs (reported by some women in my study). Organic eggs may be healthier because they come from hens that are reared on chemical free grasses, unlike the farm treated hens which are often treated with hormones to fatten them, to increase the taste of meat. Thirdly, we need to consider the differences in the combination of foods eaten with egg. In the USA, people may have scrambled eggs with cheese, sausages, home fries, and white toast. While in India, egg may be consumed in healthier forms as an egg curry along with vegetables and whole wheat Indian bread (chapathi).

Pulse and lentil preparations: There is sparse literature connecting pulse/ legume/ lentil intakes and GDM risk. More than 3 weekly servings of legumes was associated with lower GDM risk among 1026 Iranian women (OR: 0.38, 95% CI: 0.19 and 0.74) (Goshtasebi et al., 2018). Most evidence suggesting that pulses may be protective comes from global observational studies linking diet with T2DM risk. These studies have investigated the Mediterranean diet and low glycaemic diets that are rich in pulses (Ramdath et al., 2016), and have shown an inverse association with T2DM risk. A meta-analysis that included 50 studies from Europe, Israel, Australia and the USA covering 534,906 adults suggested that, greater adherence to the Mediterranean diet was inversely associated with fasting blood glucose levels (Kastorini et al., 2011). In the Greek EPIC cohort (European Prospective Investigation into Cancer and Nutrition) (N=23,349), men and women who adhered to a traditional Mediterranean diet had a reduced T2DM risk, with a median intake of pulses of about 9 grams per day (Trichopoulou et al., 2009). A meta-analysis of 10 and 14 studies investigating glycaemic index (GI) and glycaemic load (GL) respectively, in the United States, Europe, China and Japan showed that,

participants with the lowest GI and GL diets (rich in wholegrains and pulses) had a lower T2DM risk (Bhupathiraju et al., 2014). Another study in China that followed 4096 adults over 15 years suggested that greater adherence to a dietary pattern abundant in pulses, was associated with a lower T2DM risk (Batis et al., 2014). A review that included observational and intervention studies concluded that an acute intake of one cup of pulses significantly reduced the postprandial glucose response (PBGR) among T2DM patients and a weekly intake of five cups of pulses improved glycaemic profiles and decreased the risk of obesity (Ramdath et al., 2016).

There may be reasons why pulses may protect against GDM. Pulses are rich in low glycaemic index carbohydrates, protein, vitamins and minerals. They are known to slow down the breakdown of carbohydrates and lipids in the small intestine because of their fibre and natural enzyme inhibitors (American Diabetes Association, 2016). Their high soluble fibre results in gelling of the food matrix in the gut and increased satiety, by affecting hormonal and neural signals, and this sensation of fullness is enhanced by increased gastric distension and a slow emptying of food from the stomach into the small intestine (Moran et al., 2011). Additionally, the fibre in pulses may be broken down by colonic bacteria to produce SCFAs, that may release satiety related hormones (Slavin et al., 2013). The satiety producing property of pulses may play an important role in maintaining blood glucose levels and body weight, thus preventing T2DM risk (Ramdath et al., 2016, American Diabetes Association, 2016).

Fried and fast food: Most studies investigating fried and fast food and GDM risk in contrary to my findings, have shown positive associations among the US, Spanish and Iranian women (Bao et al., 2014; Dominguez et al. 2014 & Lamyian et al., 2017, details of these studies in Chapter 1, table 1.4, pages 17 - 24). These findings have been attributed to fried and fast foods containing excess calories, and high amounts of unhealthy substances such as trans-fat that may interfere with cellular insulin signals (Cahill et al., 2014). However, an important point to note is that studies have found stronger associations between fried and fast foods and GDM and T2DM risk from foods eaten outside the home, than those prepared at home. There is a higher chance of fried and fast food containing more acrolein (formed due to re-use of oil), and AGEs (advanced glycation end-products, derivatives of glucose-protein or

glucose-lipid formed at high frying temperatures) when eaten outside, than at home due to re-use of oil (Cahill et al., 2014; Bao et al., 2014). There are two possible reasons for my contradictory findings. Firstly, a chance association cannot be eliminated, especially with multiple testing of food groups. This association was not retained after multiple testing correction. Secondly, there is a difference in the concept and profile of foods that come under fried and fast foods in western countries and India. In Western settings they might include foods such as hamburgers, cheeseburgers, french fries, pizza, deep fried chicken, fried fish and hot dogs. These foods contain refined flour, oil and trans-fats, chicken, fish, pork and beef. Indian fried and fast foods including vada, papad, chakli, bhajji, gobi manchurian, chats (for food details, refer Indian food glossary, Appendix Q, page 360) and chips (made of potato or banana or jackfruit) and samosas may contain wheat or chickpea flour, vegetables such as potato. Bhajjias contain brinjal, ridge gourd, onion, banana peppers and spices. Thus, Indian fried food could be considered to be healthier than Western fried and fast food. In my study, women ate Indian fried foods very regularly (every other day on average) but western style fast foods (including, pizzas and burgers were consumed less regularly (once a month, and never in >70%). Consuming fried food in the evening as a snack may reduce the likelihood of large amount of food during dinner, owing to satiety of fatty foods (Jebb et al, 2006). This may be beneficial for maintaining blood glucose levels, when we are less active than during the day. Some evidence shows that unused oils rich in n-6 and n-3 fatty acids used for frying foods may be beneficial for blood glucose response (Farnetti et al., 2011). Hence, fried food made at home may be more likely to be fried in unused oil which may help blood glucose levels, if the fatty acids remain intact after frying. To date, there are no recommendations regarding limiting intake of fast and fried food, as it is complex. The findings of my study cannot be used to recommend women have a higher fast and fried food to prevent GDM. However, my findings make a case for to start looking at food as a wholesome entity, where cultural differences of food preparation and whether it is home-made or restaurant-bought are considered. Western and Indian fried and fast foods may both contain high levels of energy and fat but Indian foods may also contain healthy components. It may not be ideal to make universal recommendations of avoiding fried and fast food (commonly seen

among health professionals), just because nutrient wise it is high in calories and fat.

6.4. Conclusion

While food groups are representative of the peri-conceptual diet exposure in studying health outcomes, there are limitations to using them to characterise diet. In reality, foods are eaten in combinations as part of an overall diet. For instance, whole grain cereals (e.g. chapathi or brown rice or millet ball) may be consumed along with a green leafy lentil side dish (sambhar) or egg curry or boiled peanut salad, all of which individually or in combination may confer benefits. In order to overcome these issues, I will study associations between dietary patterns and GDM in the next chapter.

Chapter 7

Association between women's peri-conceptual diet patterns and development of GDM

7.1. Background and aims of this chapter

Diet patterns: 'Diet' is a complex exposure and exploring diet represented by food groups is limited by the fact that, in real life we consume a diverse combination of foods containing many nutrients - eaten together as part of a 'diet pattern' (Hu, 2002). There is likely to be co-linearity between many foods or food-groups, which makes it problematic to attribute health effects to any particular food or food-group (Hu, 2002). Additionally, if many food groups are considered in relation to an outcome, it is expected that statistically significant results may be found by chance (Tobias et al., 2012). Dietary patterns are defined as the quantities, proportions, variety or combinations of different foods and beverages in diets, and the frequency with which they are habitually consumed (Hu, 2002). Diet patterns are more representative of real life eating behaviour because we consume combinations of foods and beverages rather than single foods or food groups. The knowledge derived from studying diet patterns has the potential to inform public health recommendations and design interventions to improve women's diets (Willett & McCullough, 2008). Diet patterns best capture the totality of the 'diet' exposure, the combinations and quantities in which foods and nutrients are consumed (FAO, 1995; United States Department of Agriculture, 2015).

This chapter describes the concept of PCA methodology, the construction of food groups for PCA and their rationale. It also describes the diet patterns obtained and associations between the derived diet patterns, population characteristics and GDM using univariate and multivariate regression models. Finally, I review the concept diagram in relation to my exposure 'diet patterns', population characteristics and outcome 'GDM development' to discuss my chapter findings.

7.2. Concept of Principal Component Analysis explained

Principal Component Analysis is a dimension reduction technique, which derives a small number of linear components from a larger number of input variables (Dunteman, 1989). Unlike individual foods or food groups, these components are independent of each other and by construction explain the maximum variation in the data (Dunteman, 1989). My PCA method used the weekly frequency of intake of foods as the input variables.

PCA results in the same number of components as the number of input variables used, with the first component explaining the maximum variability in the data. As we move to each subsequent component, the variability explained reduces, shown in a 'scree plot' (Dunteman, 1989). It is important to note that the patterns derived in PCA do not necessarily define a complete eating pattern. A person with a high score on one component may have high or low scores on other components. Therefore, a person's overall diet pattern is represented by their scores across all components rather than one single component (Newby & Tucker, 2004a).

Foods with large positive or negative factor loadings on a given component are characteristic of the diet pattern represented by that component. Component factor loadings can take any value from -1 to 1. Component scores are calculated by multiplying the frequency of intake by the component factor loading for a specific food, and then summing these values for all foods or food groups in the PCA. The component scores are continuous variables and thus each woman in the study will have a score for each component (Newby & Tucker, 2004a). The higher the score, the greater is the adherence to that component or dietary pattern (Dunteman, 1989). Component scores are standardised to have a mean of 0 and a standard deviation of 1 (Crozier et al., 2006). Suppose in a component, apple has a factor loading of 0.22, almonds have a factor loading of 0.48 and fish curry has a factor loading of 0.20 for a woman who reported having apple once a week, almonds five times a week, fish curry twice a week, her 'component score' is calculated as follows:

$$\begin{array}{rcll}
 \text{Apple} & \text{Almonds} & \text{Fish curry} & \\
 (1 \times 0.22) + (5 \times 0.48) + (2 \times 0.20) & & & \\
 = & 0.22 & + & 2.40 & + & 0.40 & = & 3.02
 \end{array}$$

7.3. Methods used in the construction of the food group input variables for the PCA

There were 224 foods on the BANGLES FFQ. But among these, there were some foods not consumed by women in the study and therefore these did not contribute to the PCA. Also there were foods that women reported consuming but were not in the FFQ, these were recorded and later coded under the existing FFQ food items (2.8.4, page 87). There were 205 foods from the FFQ included in the diet pattern analysis. I collapsed these 205 foods into a smaller number of food groups, because a smaller number of input variables is helpful to make the results of the PCA more interpretable (Newby et al., 2004b).

I constructed the food groups using a mixture of *a priori* and *posteriori methods*. First, using the 205 foods on the FFQ, I created a base template of 55 food groups, built on prior knowledge of foods that had similar food and nutrient composition. For example, different types of nuts and seeds such as almonds, cashewnuts, pistachios, groundnuts, walnuts, sunflower seeds, pumpkin seeds, flax seeds, chia seeds and their preparations were grouped together. Similarly, plain boiled rice and spice seasoned rice varieties including lemon, tamarind, ghee rice varieties were grouped together (table 7.1, Appendix R, page 367). To see the glossary of the Indian foods on the FFQ, see appendix Q on page 360). Since these 55 groups were created from a nutritionist's perspective, and not from how women in real life eat based on family habits or culture preferences or cost, I decided to consider these aspects as well. Hence, I made modifications to these 55 food groups and constructed 68 food groups, by i) running a PCA with all 205 foods in the FFQ ii) noting the commonly consumed foods and iii) considering the culture-based preferences of women. The next sub-sections 7.3.1, 7.3.2 and 7.3.3 will describe the process of constructing the final 68 food groups from the 55 food groups.

7.3.1. PCA with the 205 FFQ foods

Food frequency questionnaire data, which was a recall of peri-conceptual diet, collected in early pregnancy, in BANGLES was used for the present analysis. I started with a PCA of all foods consumed (205 foods) because it is

the only way to see which food discriminates a particular diet pattern, this information may be lost when PCA is done on pre-grouped foods. For decisions involved in the PCA of 205 foods, see table 7.2 below.

Figure 7.1 shows the scree plots for the PCA of 205 food groups. Using this, I decided to retain the first five output components that represent the five diet patterns. The scree plot break, where the line becomes more horizontal, is often used to decide which components to include. From figure 7.1, we can see the break in the scree plot starts to occur after the 5th point. The Kaiser-Meyer-Olkin test (KMO) measure of sampling adequacy was 0.64 for the PCA of 205 foods, indicating that the sample size for the PCA was adequate. The first five components explained about 13.7 percent of variance in the sample (table 7.3).

Table 7.2: Decisions used to derive diet patterns, consistent across the PCA of 205 foods and 68 food groups

Dietary data to use: The FFQ gives a reasonably good picture of long-term eating behaviour and the 24-hour recall represents short-term eating behaviour (Willett, 1998). We used an FFQ in BANGLES because we wanted to measure dietary intake in the periconceptional period which we defined as the month around conception. Our study design meant that it was not possible to conduct 24-hour recalls to measure peri-conceptional diet as the women were recruited in early pregnancy. Limitations of FFQs include: i) Participants may find it difficult to recall their diet, particularly infrequently consumed foods, over a period of time (recalling food intake from the previous day is considerably easier than over a week or month). ii) FFQs require a pre-specified food list and therefore knowledge of the diet of the population of interest. This can be mitigated to an extent by including options to report ‘other foods’ but does place some burden on the participants. FFQs measure energy intake less accurately than a 24-hour recall. However, studies suggest that energy adjustment is not essential for dietary pattern studies. (Cade et al., 2002 & Thorpe et al., 2016).

Input variables to use: Diet patterns can be studied using either frequency of intake, weight of intake or percent energy contribution to the diet (Schwerin et al., 1981). I chose weekly frequency of intake of foods (that is representative of quantity) as the input variables, to make my findings more relatable to other settings, anywhere globally. For instance, units and quantified weights of foods can differ based on how a food is cooked.

Construction of food groups: There are no exact rules regarding this, but evidence indicates that a larger number of food groups may be better to explain elements of

a particular diet pattern (Newby & Tucker, 2004a) and give a more precise estimate of the disease risk (Cade et al., 2002). To justify my food grouping, I correlated the first five components derived by the PCA of 205 foods and 68 food groups (see section 7.5).

Rotation vs. no rotation: Some studies use a mathematical method of orthogonal or oblique rotation to improve pattern interpretation, as rotation changes the axes of the factor loadings, thus polarising the factor loadings closer to ± 1 . However, there is no clarity on the utility of rotation and its impact on interpretability of components. Some studies have even shown that rotation can lead to a loss of discrimination (Newby & Tucker, 2004a). In my analysis, I have used an unrotated PCA to derive the diet patterns.

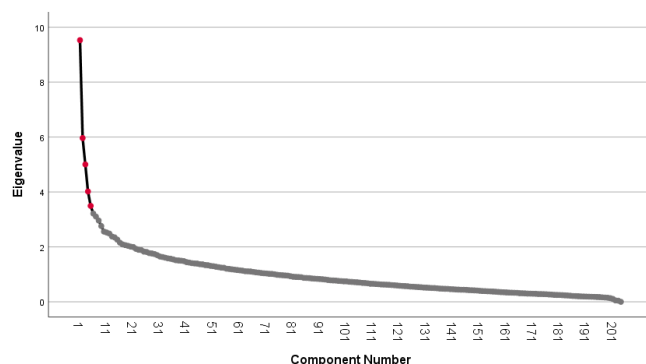
Cut-off for the factor loadings: I used a cut-off of 0.2 for the factor loadings, based on the interpretability of the diet patterns.

Naming of the diet patterns: I have used a qualitative method (Newby and Tucker, 2004a) based on the foods that are associated with the pattern and the common knowledge of settings in which diet patterns are normally known such as urban, traditional, vegetarian etc. (Newby & Tucker, 2004a).

Table 7.3: Total variance explained by PCA of 205 foods (n=785)

Component	Cumulative % of variance
1	4.65
2	7.56
3	9.98
4	11.94
5	13.64

Figure 7.1: Scree plot of PCA from 205 foods consumed by women in the FFQ (n=785)



The five diet patterns were distinct and based on their characteristics (table 7.4 that shows PCA of 205 foods), were named as follows:

Pattern 1: High-diversity, urban

Pattern 2: Rice-fried snacks-chicken-sweets

Pattern 3: Healthy, traditional vegetarian

Pattern 4: Snacks, sweets and takeaway preference

Pattern 5: Low-diversity and light eating

The purpose of doing a PCA of 205 foods was to identify pattern discriminating foods, which are foods with high factor loadings in each pattern, and which stood out in a particular pattern. This enabled me to create 68 food groups, using a cut-off of 0.2 for factor loadings of foods. Foods with factor loadings ≥ 0.2 were frequently consumed by women with a high score on that component, while foods with factor loadings ≤ -0.2 were infrequently consumed by women. Foods with factor loadings close to 0 were non-discriminatory for that component. For example, chapathi had a high factor loading of 0.38 in pattern 1, banana (yelakki) had a factor loading of 0.26 in pattern 2 and ragi ball had a factor loading of 0.35 for pattern 3 (foods marked in red in first column, table 7.4). These were considered pattern discriminating foods for patterns 1, 2 and 3. This step was essential to keep the pattern discriminating power of foods intact, which may be lost if they are grouped together. I decided to keep these foods as separate groups when constructing the food group input variables from the base template of 55 foods. The PCA of 205 foods served as a good template to devise grouping of foods, to actually see how foods appear distinctly in each pattern and get detailed elements of each diet pattern.

Table 7.4: Unrotated PCA of 205 FFQ foods showing factor loadings of the first 5 diet patterns (n=785)

Foods in the FFQ	Pattern 1 High-diversity, urban	Pattern 2 Rice-fried snacks- chicken- sweets	Pattern 3 Healthy, traditional vegetarian	Pattern 4 Snacks, sweets and take away preference	Pattern 5 Low- diversity and light eating
Beverages:					
Tea	0.01	0.21	-0.21	0.09	0.20
Coffee	-0.09	0.14	0.09	0.06	0.30

Foods in the FFQ	Pattern 1 High-diversity, urban	Pattern 2 Rice-fried snacks- chicken- sweets	Pattern 3 Healthy, traditional vegetarian	Pattern 4 Snacks, sweets and take away preference	Pattern 5 Low- diversity and light eating
Normal cow's milk (as plain milk / Horlicks etc.)	0.17	-0.06	0.24	0.02	-0.48
Skimmed cow's milk (as plain milk / Horlicks etc.)	0.09	-0.10	0.01	0.08	-0.01
Buttermilk	-0.03	0.15	0.36	0.00	0.04
Horlicks, Complan, Boost & Bournvita	0.14	-0.04	0.14	0.12	-0.35
Pro PL	-0.08	-0.01	0.00	-0.01	-0.02
Baby & me	0.03	0.04	0.08	0.09	-0.15
Pristine Balance PL	0.01	0.03	0.01	0.07	-0.01
Nutri-right Mom	-0.01	-0.05	0.01	0.03	0.04
GRD Smart	-0.02	-0.01	0.03	0.05	-0.07
Protovic DF	-0.01	0.03	0.08	0.01	-0.02
Glucon D	0.03	0.05	0.08	0.09	-0.15
Hersheys chocolate syrup	0.06	0.09	-0.03	0.07	-0.05
Badam milk	0.13	0.10	0.11	-0.05	-0.26
Electoral	0.01	0.08	0.04	-0.04	0.00
Tender coconut water	0.21	0.07	0.21	-0.05	-0.13
Sugarcane juice	0.17	0.17	-0.01	0.06	0.08
Packaged fruit juice (Real, tropicana etc.)	0.24	0.05	-0.17	0.04	-0.03
Fresh vegetable soups	0.23	-0.05	0.06	0.03	0.09
Fresh non - veg soups	0.20	0.07	-0.12	-0.14	-0.14
Ready to make soups	0.11	-0.03	-0.05	0.05	0.03
Carbonated beverages	0.27	0.21	-0.23	0.06	-0.01
Frooti / maaza / slice / nimbooz / appy fizz	0.14	0.20	-0.09	0.10	-0.16
Squashes / syrups (tang/kisan/ rasna/ roohafza/lemonade)	0.09	0.07	-0.11	0.00	-0.16
Fresh fruit juice specify fruit	0.30	0.03	0.13	0.00	-0.07
Milkshakes	0.19	0.07	-0.08	-0.06	-0.16
Herbal drinks	0.15	-0.05	0.05	-0.10	-0.13
Fruits:					
Apple	0.22	0.12	0.26	-0.06	-0.18
Banana (pacche/robusta) kerala type)	0.15	0.11	0.01	0.03	-0.06
Banana (yelakki)	0.12	0.26	0.18	-0.07	0.02
Sweetlime	0.15	0.15	0.22	-0.10	-0.07
Guava	0.12	0.06	0.09	0.02	0.12
Pomegranate	0.25	0.16	0.25	-0.08	-0.24
Sapota	0.14	0.09	0.14	-0.09	-0.02
Grapes (green)	0.20	0.06	0.14	0.10	-0.02
Musk melon	0.27	-0.10	0.12	0.06	0.11
Pear	0.28	-0.11	0.06	0.04	0.20
Papaya	0.32	-0.09	0.14	-0.06	0.11
Pineapple	0.18	0.12	0.02	0.07	0.00
Mixed fruit salad	0.13	0.01	-0.06	-0.09	0.02
Avocado	0.22	-0.23	0.06	-0.10	0.10
Dried fruits and nuts:					
Dates	0.28	0.16	0.24	-0.21	-0.19
Raisins	0.28	0.09	0.29	-0.13	-0.22
Figs	0.25	-0.06	0.09	-0.24	-0.15
Prunes	0.20	-0.19	0.10	-0.13	0.02
Cashew nut	0.27	0.11	0.21	-0.20	-0.27
Almond	0.48	-0.05	0.17	-0.20	-0.24
Pistachios	0.26	0.07	0.09	-0.27	-0.17
Apricots	0.21	-0.01	0.11	-0.18	-0.14
Sunflower seeds	0.04	-0.04	0.04	-0.06	-0.22

Foods in the FFQ	Pattern 1 High-diversity, urban	Pattern 2 Rice-fried snacks- chicken- sweets	Pattern 3 Healthy, traditional vegetarian	Pattern 4 Snacks, sweets and take away preference	Pattern 5 Low- diversity and light eating
Pumpkin seeds	0.14	-0.16	0.04	-0.17	-0.20
Flaxseeds	-0.06	-0.04	0.01	0.19	0.01
Walnuts	0.28	-0.37	0.14	-0.08	-0.07
Groundnuts	0.09	0.15	0.17	0.01	0.05
Rice and wheat foods:					
Plain/boiled rice	-0.33	0.44	0.11	-0.02	0.06
Red rice	0.02	-0.09	-0.09	-0.15	-0.04
Brown rice	0.02	-0.09	0.07	0.00	0.08
Rice with dal / sambhar	-0.14	0.31	0.13	-0.04	0.10
Rice with glv specify glv:	-0.09	0.30	0.32	-0.14	0.07
Spice Seasoned/ flavoured rice (tamarind / lemon / ghee / tomato)	-0.08	0.45	0.22	-0.03	0.07
Vegetable bath / bisi bele bath / veg khichdi	0.14	0.22	0.23	0.07	0.05
Curd rice	0.09	-0.02	0.21	0.16	0.11
Rice vermicelli / avalakki/ puffed rice (mandakki)	0.24	-0.14	0.14	0.24	0.14
Idly	0.16	0.12	-0.14	0.04	0.11
Plain dosa	0.11	0.14	-0.14	0.06	0.13
Masala dosa	0.28	0.13	-0.07	0.20	-0.10
Rice roti	0.10	0.10	0.24	0.00	0.08
Rice puttu/ kadabu	0.04	-0.02	-0.16	-0.07	0.00
Chapati	0.38	-0.29	-0.01	0.17	-0.01
Poori	0.22	0.23	-0.05	0.12	0.04
Parantha	0.30	-0.25	-0.08	0.19	0.01
Sweet bun / kara bun	0.06	0.16	-0.12	0.07	-0.01
Sliced white bread	0.11	0.30	0.02	0.06	-0.08
Sliced brown bread	0.31	-0.34	-0.08	0.00	0.03
Uppuma	0.16	0.08	0.21	0.14	0.14
Broken wheat / dalia	0.15	-0.15	0.08	0.11	0.11
Wheat flakes	0.13	-0.12	0.02	-0.02	0.05
Pasta / macaroni	0.33	-0.10	-0.22	-0.01	0.06
Spaghetti / noodles	0.27	0.01	-0.22	0.14	-0.10
Ragi foods:					
Ragi roti	0.04	0.09	0.28	0.01	0.01
Ragi ball	-0.33	0.30	0.34	-0.16	0.08
Ragi dosa	0.05	0.03	0.22	-0.03	0.05
Ragi Malt / Malt / Ganji	0.01	0.08	0.09	-0.04	-0.08
Ragi vermicelli	0.05	0.00	0.06	0.00	0.02
Ready to eat breakfast cereals:					
Oat + milk	0.15	-0.16	0.01	-0.09	0.04
Oats + water	0.20	-0.17	0.03	-0.12	0.03
Muesli	0.26	-0.22	0.04	-0.07	-0.08
Corn flakes (plain)	0.10	-0.06	0.01	-0.05	0.00
Corn flakes (with dryfruit)	0.32	-0.19	0.01	-0.11	0.05
All bran flakes	0.20	0.02	0.03	-0.04	-0.05
Chia seeds	0.25	-0.20	0.15	-0.18	-0.03
Pulse and lentil foods:					
Urad vada	0.21	0.16	-0.15	0.03	0.05
Chilas / adai / pesarattu	0.22	-0.11	-0.01	0.06	0.15
Pulse and vegetable sides:					
Legume based dhal	0.12	0.13	0.22	-0.04	-0.08
Split lentil based dhal	0.08	-0.14	0.11	0.09	0.13
Potato palya	0.26	0.14	-0.23	0.06	0.12
Carrot palya	0.26	0.04	0.14	-0.05	0.15
Mixed veg sambhar	-0.12	0.24	0.14	-0.03	0.18
GlV / soppu sambhar	-0.11	0.36	0.34	-0.21	0.11

Foods in the FFQ	Pattern 1 High-diversity, urban	Pattern 2 Rice-fried snacks- chicken- sweets	Pattern 3 Healthy, traditional vegetarian	Pattern 4 Snacks, sweets and take away preference	Pattern 5 Low-diversity and light eating
Beetroot, radish, yam, tapioca palya	0.24	0.18	0.16	-0.13	0.14
Ladysfinger palya	0.30	0.01	-0.03	0.11	0.18
Cabbage / knol khol palya	0.27	-0.03	-0.01	0.03	0.26
Cauliflower palya	0.48	-0.03	-0.21	0.07	0.22
Chow chow, pumpkin, gourds	0.29	-0.08	0.11	0.13	0.27
Capsicum palya	0.34	-0.06	0.12	0.17	0.18
Drumstick palya	0.14	0.18	0.00	-0.08	0.17
Brinjal palya	0.29	0.08	-0.07	0.07	0.18
Beans playa	0.33	0.10	0.08	0.00	0.08
Mushroom palya	0.34	-0.03	-0.08	-0.07	0.14
Gl v / soppu palya	0.16	0.25	0.23	-0.20	0.18
Multi vegetable saagu	0.24	0.05	0.10	0.07	0.13
Rasam	0.05	0.20	0.09	0.03	0.04
Raw vegetables and salads:					
Cucumber (without skin)	0.33	0.03	0.31	-0.04	0.08
Tomato	0.40	-0.12	0.10	0.10	-0.05
Onion	0.22	-0.13	-0.03	0.05	-0.03
Carrot	0.33	0.03	0.31	-0.13	-0.08
Radish	0.21	0.00	0.10	-0.17	0.12
Kosambari	0.11	0.10	0.36	0.00	0.00
Runner beans	0.04	0.18	0.18	-0.10	0.00
Raw Greens	0.27	-0.11	0.13	-0.24	-0.04
Non-vegetarian preparations:					
Chicken biriyani	0.14	0.38	-0.30	-0.30	-0.13
Chicken fry	0.22	0.30	-0.36	-0.37	0.00
Chicken curry/ sambhar	0.14	0.33	-0.26	-0.36	0.08
Fish fry	0.28	0.07	-0.29	-0.28	-0.02
Fish curry	0.19	-0.01	-0.22	-0.12	0.06
Fish cutlet	0.13	-0.02	-0.25	-0.13	0.07
Dried fish / dried seafood	0.12	0.10	-0.17	-0.06	0.10
Prawn, crab, shellfish	0.34	-0.07	-0.21	-0.26	0.19
Lamb, beef, pork- fry	0.10	0.18	-0.24	-0.20	-0.09
Lamb, beef, pork - cutlet	0.05	0.00	-0.06	-0.06	-0.07
Lamb, beef, pork - curry	0.19	0.20	-0.29	-0.33	0.19
Liver, brain, kidney	0.19	0.16	-0.21	-0.15	0.11
Keema curry	0.36	0.09	-0.23	-0.32	0.21
Mutton biriyani	0.25	0.19	-0.26	-0.24	-0.13
Egg biriyani	0.07	0.27	0.00	-0.05	-0.15
Egg - boiled (with yolk)	0.12	0.27	-0.06	-0.24	-0.03
Egg - boiled (without yolk)	0.06	-0.10	0.05	-0.07	0.02
Egg burchi, curry	0.27	0.09	-0.22	-0.32	0.00
Omelette with yolk	0.21	0.26	-0.20	-0.19	-0.02
Omelette without yolk	0.01	0.06	0.11	0.02	-0.10
Condiments:					
Pickle (lemon / mango)	0.12	0.28	0.02	0.24	0.05
Coconut chutney	0.18	0.16	-0.01	0.07	0.15
Groundnut chutney	0.02	0.17	0.03	0.03	0.01
Tomato Ketchup	0.31	-0.10	-0.12	0.23	-0.02
Jam	0.21	0.19	0.02	0.00	-0.03
Honey	0.29	-0.24	0.04	-0.09	-0.04
Other chutneys and powders	0.10	-0.22	-0.04	0.05	0.01
Added sugar and jaggery:					
Sugar in fruit juice	0.16	0.18	0.05	-0.08	-0.13
Sugar in tea	-0.04	0.22	-0.20	0.06	0.21
Sugar in coffee	-0.12	0.17	0.09	0.04	0.30
Sugar in milk	0.10	0.04	0.18	0.05	-0.44
Jaggery	0.12	-0.19	0.14	0.10	0.09
Savoury (salted) snacks:					

Foods in the FFQ	Pattern 1 High-diversity, urban	Pattern 2 Rice-fried snacks-chicken- sweets	Pattern 3 Healthy, traditional vegetarian	Pattern 4 Snacks, sweets and take away preference	Pattern 5 Low- diversity and light eating
Papad/ sandige (home fried)	0.19	0.25	0.01	0.20	0.08
Namkeen/mixtures/savouries	0.15	0.24	-0.04	0.29	-0.07
Chakli/murukku/kodbale	0.11	0.34	0.04	0.24	-0.03
Pakoda/bonda/bhajji/samosa	0.07	0.28	-0.14	0.21	0.04
Babycorn / gobi manchurian	0.21	0.31	-0.04	0.28	-0.11
Boiled / roasted corn	0.23	0.12	0.08	-0.01	0.09
Chips (potato/plantain/fries)	0.20	0.28	-0.18	0.24	-0.21
Puff	0.14	0.34	-0.07	0.12	-0.02
Chats (masala puri, pani puri, bhel puri)	0.22	0.23	-0.10	0.38	-0.16
Sweet snacks:					
Chocolate*specify brand:	0.35	0.12	-0.13	0.18	-0.25
Toffee/ candy	0.15	0.07	-0.15	0.23	-0.19
Cake without cream	0.20	0.17	-0.03	0.05	-0.06
Cake with cream / pastry	0.17	0.26	-0.08	0.14	-0.03
Sweet biscuits	0.13	0.19	0.07	0.17	-0.07
Salted biscuits	0.16	0.10	-0.15	0.11	-0.02
Cream biscuits	0.18	0.10	-0.04	0.20	-0.06
Kesaribaath	0.12	0.17	0.00	0.15	-0.03
Obbattu/holige	-0.02	0.08	0.07	0.02	0.01
Barfi /pedha	0.16	0.11	0.00	0.08	-0.06
Gulab jamoon, jalebi. jangir	0.14	0.20	-0.08	0.12	-0.08
Chikki	0.08	-0.01	0.01	0.09	-0.10
Laddoo, Mysore pak	0.14	0.12	-0.05	0.25	-0.09
Halwa (dumroot/carrot)	0.24	0.04	-0.03	0.13	-0.01
Kheer/ payasam	0.01	0.03	0.04	0.00	0.07
Bengali sweets	0.24	0.08	-0.12	0.25	-0.05
Pudding/custard/cheese cake	0.19	-0.05	-0.18	-0.03	-0.11
Fast food:					
Veg pizza	0.31	-0.18	0.02	0.23	-0.05
Non veg pizza	0.25	0.00	-0.39	-0.11	-0.04
Veg burger	0.22	-0.08	-0.07	0.29	-0.16
Non veg burger	0.16	0.02	-0.32	-0.02	-0.19
Milk products:					
Curd	0.17	-0.02	0.27	0.16	0.00
Raitha (any vegetable raita)	0.17	0.14	0.02	0.04	0.06
Butter	0.26	0.01	-0.09	0.07	0.10
Ghee on the plate/ table	0.21	0.00	0.23	0.13	0.00
Cheese (all types)	0.32	-0.23	-0.07	-0.03	-0.04
Paneer curry	0.50	-0.35	-0.01	0.15	0.00
Paneer tikka	0.12	-0.04	0.00	0.09	0.00
Icecreams (all types)	0.32	0.18	-0.13	0.23	0.00
Seasonal foods:					
Raw mango	0.06	0.26	0.14	0.05	0.07
Ripe mango	0.22	0.01	0.10	0.04	0.12
Jackfruit	0.11	0.14	0.23	-0.06	0.10
Avrekalu (green beans)	-0.07	0.22	0.18	0.03	0.16
Orange	0.34	0.00	0.27	-0.08	-0.02
Green peas	0.37	-0.17	0.07	0.05	0.28
Purple grapes	0.18	0.07	0.01	-0.06	0.06
Watermelon	0.34	0.05	0.08	-0.02	0.09
Litchi	0.40	-0.20	0.08	-0.06	0.27
Amla	0.17	0.06	0.12	0.04	0.01
Jamun	0.15	0.04	0.06	0.05	0.13
Plum	0.29	-0.07	-0.07	-0.21	0.12
Custard apple	0.23	-0.01	0.12	0.00	0.15
Strawberry	0.48	-0.13	0.05	-0.15	0.09

Lighter shadings: positive factor loadings ≥ 0.2 , Darker shadings: negative factor loadings

Foods in the FFQ	Pattern 1 High-diversity, urban	Pattern 2 Rice-fried snacks- chicken- sweets	Pattern 3 Healthy, traditional vegetarian	Pattern 4 Snacks, sweets and take away preference	Pattern 5 Low- diversity and light eating
≤ -0.2	Factor loadings ≥ 0.2 for pattern 1;	Factor loadings ≤ -0.2 for pattern 1	Factor loadings ≥ 0.2 for pattern 2;	Factor loadings ≤ -0.2 for pattern 2	Factor loadings ≥ 0.2 for pattern 3;
	Factor loadings ≥ 0.2 for pattern 3;	Factor loadings ≤ -0.2 for pattern 1	Factor loadings ≥ 0.2 for pattern 4;	Factor loadings ≤ -0.2 for pattern 1	Factor loadings ≥ 0.2 for pattern 5;
	Factor loadings ≥ 0.2 for pattern 5;	Factor loadings ≤ -0.2 for pattern 1			

7.3.2. Commonly consumed foods

For foods that were consumed daily by the majority of women, I created input variables comprising only those commonly consumed foods. For example, rice, ragi ball, chapathi, banana etc. This step was important to prevent the commonly consumed foods from diluting the discriminating power of the diet patterns. For example, bananas were frequently consumed by most women in the study and hence I created a food group comprising only banana. Other fruits were consumed less frequently and not by all women so these were more discriminatory. If bananas and other fruit were all grouped together, the PCA may not discriminate between the women in terms of their fruit intake because the universal consumption of bananas would mean that the factor loading for fruit would be close to zero. Some other commonly consumed foods were tea, coffee, plain boiled white rice, ragi ball, chapathi, dates, almonds, raisins, apple, dal and curds. Each of these was grouped separately.

Fruits and dried fruits are important contributors to micronutrient intakes and people generally have preferences based on taste, availability and affordability. From the PCA of 205 foods, I noticed that the first pattern 'High-diversity, urban' diet pattern was characterised by more frequent intake of all fruits. The second pattern 'Rice-fried snacks-chicken' pattern showed more frequent intake of only banana, and the third diet pattern 'Healthy, traditional vegetarian' showed more frequent intake of apple, sweet lime and pomegranate. These fruits characteristic of pattern one, two and three were grouped separately. The rest of the fruits, that were not characteristic of any particular dietary pattern, were all grouped together as 'other fruits'.

7.3.3. Culture-based preferences of women

Lastly, I grouped and ungrouped foods based on culture and preferences, from my knowledge and observations made during data collection. It is well-known that Indian food habits are diverse and can vary every 100 kilometres (Begum et al., 1998). Although my study consisted of women from urban and rural Bangalore, I have observed that women carry their food habits from the place they hail from - to where they migrate. Each household usually has a specific preferred staple food that is consumed daily – either whole wheat chapathi, rice or ragi ball or dosa or jowar roti, and so on. Hence I kept these cereal based staple foods separate. For instance, women who are originally from South Karnataka traditionally have rice and ragi ball as their staple cereals, reflected in diet patterns 2 and 3 (table 7.4).

Idly, dosa, rice roti, rice and spice seasoned/flavoured rice are all primarily rice foods but they are consumed in different ways across Karnataka state (Devdas, 1999). For example, urban women generally have access to packaged instant idly and dosa batters and consume idly and dosa more frequently than rural women. Although idly and dosa are similar in ingredients - both made by fermenting and grinding of rice and black gram, a separate group was created for dosa because it is consumed as a staple by women from coastal Karnataka. On the other hand, in urban metropolitan areas, dosa is a popular restaurant food consumed regularly. Hence, dosa is eaten with different foods by different groups.

Rice roti, kadabu and puttu are traditional rice specialities made by a few women, particularly in rural areas (Devdas, 1999). Rice is eaten as a breakfast dish by many families, though it is technically white rice. Therefore, I created separate groups for each of these foods. Traditional green leafy vegetable (GLV) dishes such as drumstick and other GLV palyas (side dishes) were kept separate from other greens such as cabbage and cauliflower, which are generally consumed in urban areas.

While grouping foods, I focussed also on how women generally eat and not only from a nutritionist's perspective. For instance, from a nutrition perspective, brown bread and chapatti are both made of wholegrain wheat, are a good source of fibre and have similar calorie-content. But women usually think less from a nutrient perspective and make food choices based on

cultural inclination. I applied this concept to the grouping of foods. For example, breads, bun, pasta, noodles etc. were grouped as western cereal products, separate from traditional Indian wheat breads such as chapathi or poori. Also, women usually tend to consume either ghee or butter so these foods were grouped separately. Women who make traditional sweets such as obattu, kheer and kesaribaath at home have less shop bought sweets such as gulab jamun, laddoo or carrot halwa. Hence I created separate groups for traditional home-cooked sweets (including obattu, kheer and kesaribaath) and shop-bought Indian sweets (including gulab jamun, laddoo or carrot halwa and others).

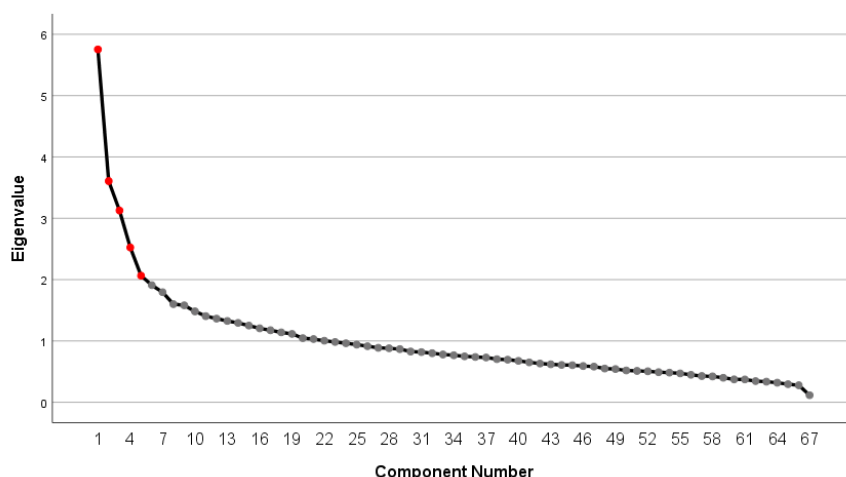
Foods that were not making a meaningful contribution to discrimination of diet patterns were regrouped. For example, fish curry, fish fry, dried fish, fish cutlet and seafoods prawn, crab and shellfish were kept separate as an experiment with the PCA, but later I regrouped them together as fish preparations. All these food grouping decisions (7.3.1, 7.3.2 and 7.3.3) led me to collapse 205 foods in the FFQ to 68 food groups.

7.4. Results of the PCA with the 68 food groups

The 205 foods that were consumed in the FFQ were condensed to 68 food groups based on the rationale presented in section 7.3. A PCA was run with these final 68 food groups, and again the first five components were retained in the analysis. Table 7.6, page 193 shows their factor loadings for the first five components without rotation. Foods with factor loadings ≥ 0.2 were frequently consumed by women with a high score on that component whilst foods with factor loadings ≤ -0.2 were infrequently consumed by women with a low score on that component. Foods with factor loadings close to 0 were non-discriminatory for that component. Figure 7.2 shows the scree plots for the 68 food group PCA. The number of output variables/ components was also decided based on the scree plot. We can see that the break in the scree plot, starts to occur at the 6th point, meaning the first 5 components/ patterns need to be retained. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.73 for the 68 food group analysis, indicating the adequacy of my sample size for PCA. The first five components explained 25.4 percent of variance in the sample (table 7.5, page 192).

Table 7.5: Total variance explained by PCA of 68 food groups (n=785)

Component	Cumulative % of variance
1	8.587
2	13.970
3	18.637
4	22.404
5	25.484

Figure 7.2: Scree plot of PCA of the 68 food groups (n=785)

By comparing the diet patterns in the PCA of 205 foods to the PCA of 68 food groups, we can see that the diet patterns are similar (table 7.6), namely:

Pattern 1: High-diversity, urban

Pattern 2: Rice-fried snacks-chicken-sweets

Pattern 3: Healthy, traditional vegetarian

Pattern 4: Snacks, sweets and takeaway preference

Pattern 5: Unpolished rice-cooked vegetables-fish

The fifth diet pattern was slightly different between the 205 and 68 food group PCAs, and was therefore named differently.

Table 7.6: PCA of 68 food groups showing factor loadings of the first 5 diet patterns (n=785)

	Pattern 1 High-diversity, urban	Pattern 2 Rice-fried snacks- chicken- sweets	Pattern 3 Healthy, traditional vegetarian	Pattern 4 Snacks, sweets & take away preference	Pattern 5 Unpolish ed rice- cooked vegetable s-fish
Beverages:					
Tea and coffee	0.04	0.33	-0.20	0.22	0.31
Cows milk	0.21	-0.16	0.25	0.01	-0.32
Fermented dairy products	0.06	0.27	0.34	0.11	0.02
Flavoured nutrient enriched sweetened supplements	0.17	-0.13	0.15	0.02	-0.26
Flavoured sweetened beverages	0.38	0.12	-0.10	-0.01	-0.31
Therapeutic beverages	0.25	0.10	0.22	-0.05	-0.13
Soups	0.20	0.16	-0.02	0.11	0.11
Fresh fruit juices	0.31	-0.04	0.14	0.06	0.00
Fruits:					
Other fruits	0.41	-0.08	0.19	-0.04	0.10
Banana (yelakki and robusta)	0.31	0.26	0.12	0.00	-0.02
Apple	0.28	0.11	0.28	-0.10	-0.24
Pomegranate	0.33	0.12	0.26	-0.13	-0.18
Sweetlime	0.21	0.12	0.27	-0.13	-0.09
Dried fruits, nuts and seeds:					
Dried fruits (figs, prunes & apricots)	0.30	-0.14	0.26	-0.32	-0.05
Dates and raisins	0.42	0.07	0.39	-0.26	-0.12
Other nuts and seeds	0.49	-0.07	0.38	-0.27	-0.08
Almonds	0.51	-0.16	0.28	-0.28	-0.11
Rice and wheat foods:					
Plain boiled white rice	-0.24	0.59	0.01	0.02	-0.15
Spice seasoned preparations	0.09	0.50	0.13	0.06	-0.02
Unpolished rice	0.00	-0.14	0.03	-0.15	0.20
Rice with dal/sambhar	-0.08	0.44	0.07	0.02	0.11
Idly	0.20	0.02	-0.21	0.00	0.22
Rice and greens preparation	-0.02	0.42	0.26	-0.05	0.04
Curd rice	0.11	0.03	0.23	0.34	0.17
Cereal preparations (upma etc.)	0.27	-0.09	0.14	0.33	0.21
Dosa and masala dosa	0.27	0.04	-0.25	0.09	0.20
Fried cereal dishes (poori & Parantha)	0.34	-0.16	-0.10	0.15	0.03
Fried pulse preparations (vada)	0.30	0.00	-0.19	0.01	0.15
Chapathi	0.34	-0.47	0.02	0.17	0.09
Processed shop bought western-style breads and extruded cereals (pasta, noodles etc.)	0.39	0.03	-0.22	0.01	-0.07
Rice roti & kadabu	0.14	0.07	0.16	0.02	0.15
Ready to eat breakfast cereals:					
Ready to eat breakfast cereals	0.28	-0.31	0.08	-0.08	0.18
Ragi foods:					
Millet preparations (jowar/ragi roti, dosa, malt & vermicelli)	0.13	0.13	0.23	0.05	-0.03
Ragi ball	-0.27	0.53	0.28	-0.08	-0.05
Pulse and vegetable sides:					
Traditional whole and split pulse preparations	0.06	0.26	0.22	0.11	0.22
Roots and tuber palyas (potato, carrot & beetroot/ radish/yam & tapioca)	0.40	0.09	-0.06	-0.07	0.28

	Pattern 1 High-diversity, urban	Pattern 2 Rice-fried snacks- chicken- sweets	Pattern 3 Healthy, traditional vegetarian	Pattern 4 Snacks, sweets & take away preference	Pattern 5 Unpolish ed rice- cooked vegetable s-fish
Other vegetables sides (ladys finger, gourds, pumpkin, capsicum, brinjal, beans, mushroom & multiveg. saagu)	0.54	-0.06	0.03	0.14	0.37
Traditional style GLV sides (GLV sambhar, GLV palya and drumstick palya)	0.10	0.48	0.28	-0.13	0.18
GLV sides (cabbage/knol khol palya and cauliflower palya)	0.38	-0.17	-0.11	0.03	0.38
Raw vegetables and salads:					
Raw vegetables (cucumber, tomato, onion, carrot, radish, runner beans and raw greens)	0.46	-0.07	0.29	0.00	0.07
Kosambari (traditional South Indian lentil vegetable salad)	0.11	0.10	0.36	0.00	0.00
Non-vegetarian preparations:					
Chicken (fry, curry/sambhar)	0.24	0.25	-0.39	-0.47	0.05
Chicken biriyani	0.20	0.28	-0.35	-0.41	-0.01
Fish (fry, curry, cutlet, dried fish/dried seafood/prawn, crab & shellfish)	0.28	-0.07	-0.26	-0.33	0.20
Red meat (fry, cutlet, curry, organ meat, keema curry, ham salami bacon & mutton biriyani)	0.29	0.12	-0.27	-0.38	0.07
Boiled egg	0.21	0.17	-0.04	-0.38	0.09
Egg preparations (egg biriyani, egg burchi, omelette)	0.32	0.17	-0.28	-0.38	0.11
Condiments:					
Pickles, papads, chutneys & chutney powders	0.33	0.27	-0.14	0.29	0.01
Western condiments (ketchup & instant soups)	0.29	-0.22	-0.14	0.19	-0.04
Added sugar:					
Added sugar (sugar in tea, coffee, milk, fruit juice, jam, honey & jaggery)	0.17	0.30	-0.07	0.21	0.19
Savoury snacks:					
Medium calories fried savoury snacks (namkeen & chakli)	0.27	0.27	-0.16	0.27	-0.25
High calories savoury fried snacks (pakoda/bhajji/samosa)	0.32	0.26	-0.39	0.21	-0.26
Puff pastry snacks	0.23	0.28	-0.20	0.06	-0.10
Chats	0.28	0.10	-0.23	0.24	
Sweet snacks:					
Chocolate	0.31	-0.05	-0.23	0.17	-0.29
Creamless & cream cake	0.32	0.17	-0.20	0.08	-0.15
Sweet, cream & salted biscuits	0.29	0.13	-0.08	0.20	-0.18
Traditional, home-made cereal based sweets (kesaribaath, kheer & holige)	0.18	0.26	-0.07	0.16	0.02
Traditional shop bought fried sweet preparation (khoa based sweets - barfi, pedha, jamoon, laddoo, halwa and other sweets)	-0.16	-0.14	0.12	-0.12	-0.03

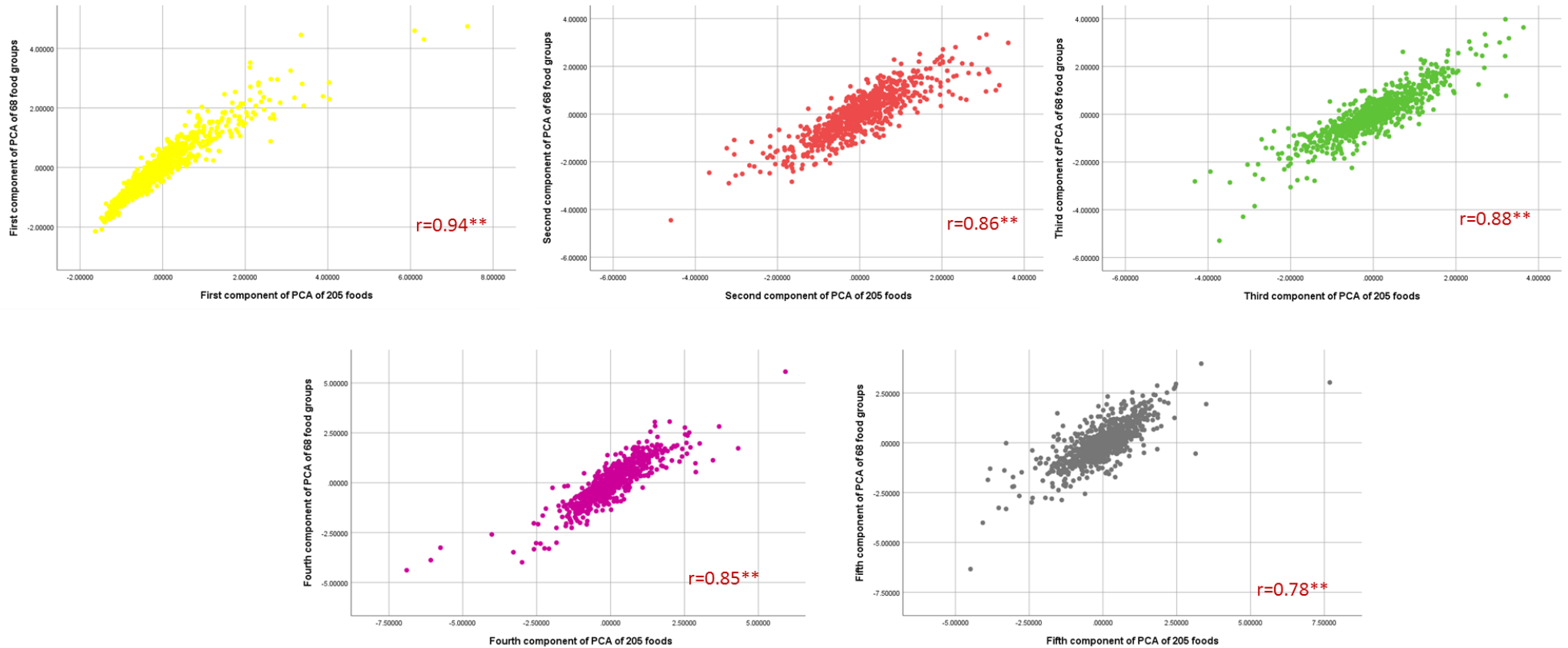
	Pattern 1 High-diversity, urban	Pattern 2 Rice-fried snacks- chicken- sweets	Pattern 3 Healthy, traditional vegetarian	Pattern 4 Snacks, sweets & take away preference	Pattern 5 Unpolish ed rice- cooked vegetable s-fish
Western style desserts (cheesecakes, custards, puddings)	0.16	-0.15	-0.16	-0.09	-0.12
Fast food:					
Fast food (veg and non-veg pizza and burger)	0.34	-0.25	-0.22	0.10	-0.22
Milk products:					
Curd/ yogurt	0.21	0.00	0.32	0.33	0.04
Ghee	0.24	-0.03	-0.12	0.09	0.05
Butter	0.26	0.00	0.26	0.23	-0.01
Cheese and paneer	0.38	-0.39	0.00	0.02	0.01
Milkshakes and ice creams	0.40	0.03	-0.22	0.04	-0.20
Seasonal foods:					
Seasonal fruits	0.48	0.03	0.22	-0.02	0.07
Seasonal green beans & peas	0.15	0.17	0.11	0.14	0.25
Lighter shading: positive factor loadings ≥ 0.2 ; Darker shadings: negative factor loadings ≤ -0.2					
Factor loadings ≥ 0.2 for pattern 1; Factor loadings ≤ -0.2 for pattern 1					
Factor loadings ≥ 0.2 for pattern 2; Factor loadings ≤ -0.2 for pattern 2					
Factor loadings ≥ 0.2 for pattern 3; Factor loadings ≤ -0.2 for pattern 1					
Factor loadings ≥ 0.2 for pattern 4; Factor loadings ≤ -0.2 for pattern 1					
Factor loadings ≥ 0.2 for pattern 5; Factor loadings ≤ -0.2 for pattern 1					

7.5. Correlation between the first five components derived from PCA of 205 foods and 68 food groups

Some authors argue that food grouping in PCA is arbitrary and may affect the results (Newby & Tucker, 2004a). There are no 'rules' by which to construct food groups in PCA; it is to some extent subjective to a researcher's perspectives (Newby and Tucker, 2004a). Food grouping can be based on similar nutrients, food-composition, energy density (Newby & Tucker, 2004a) and cost of foods. The method I used has been described in section 7.3. I aimed to test whether I had done this too subjectively, by exploring correlations between the components obtained from 205 and 68 food group PCAs. Figure 7.3 shows that there were strong correlations between the first five components or diet patterns derived by both (PCA of 205 foods and 68 food groups), suggesting that despite the subjectivity of the methods, this did not lead to much difference in the results

Chapter 7

Figure 7.3: Correlations of the first five diet patterns derived by PCA of 205 foods and 68 food groups (n=785)

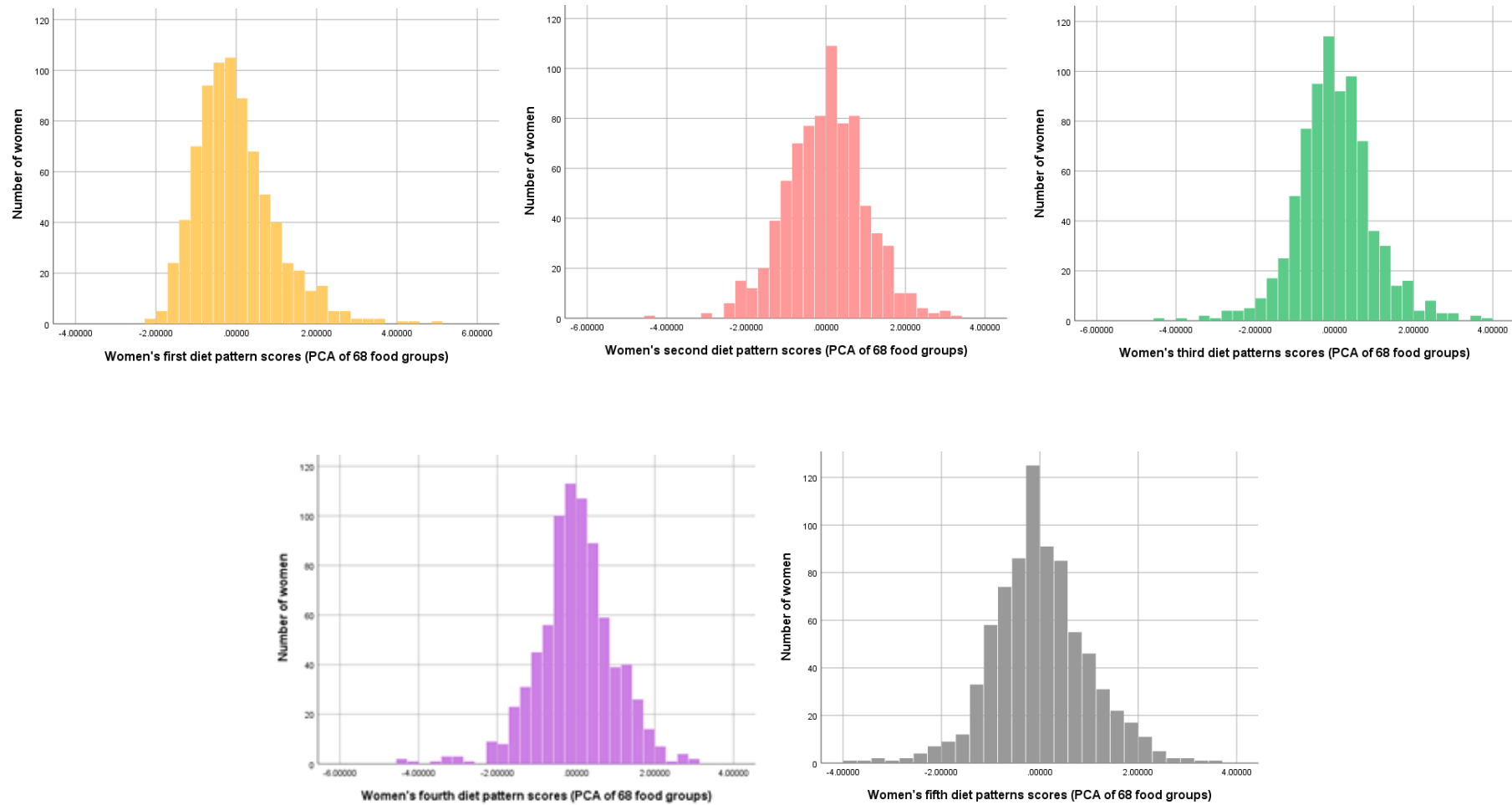


r refers to Spearman's correlations; **indicates highly significant correlations of p value <0.001

7.6. Distribution of the Principal components derived from PCA of 68 food groups

Figure 7.4 shows that all the 5 components or diet pattern variables were normally distributed.

Figure 7.4: Histograms of diet pattern scores for PCA of 68 food groups (n=785)



7.7. Foods that characterise the five peri-conceptional diet patterns derived from the PCA of 68 food groups

The 5 diet patterns derived from the PCA of 68 food groups have characteristic foods appearing in the respective diet patterns (table 7.6, page 193) and this section describes these details. To know more about Indian foods, see appendix Q, the glossary of Indian foods on page 357.

The first diet pattern is indicative of a ‘High-diversity urban’ pattern, which suggests that women with high scores were affluent, having a more frequent intake of a wide diversity of vegetarian and non-vegetarian home cooked traditional dishes, processed shop bought foods, as well as fruits and vegetables. This pattern showed high factor loadings for milk, flavoured sweetened beverages (glucose water, aerated beverages such as coke, packaged fruit juices such as Tropicana, flavoured fruit drinks and squashes, traditional beverages such as badam milk, sugarcane juice) and therapeutic beverages (tender coconut water and electoral). Vegetarian and non-vegetarian soups, fresh fruit juices also had higher factor loadings in this pattern. Fruit intake was diverse with intakes of banana, apple, pomegranate, sweet lime, chickoo, green grapes, guava, papaya, pear, pineapple, mixed-fruit salad and avocado. This pattern also included almonds, dates, raisins and expensive foods marketed recently as superfoods (figs, prunes and apricots, pistachios, cashewnuts, walnuts, groundnuts, sunflower seeds, pumpkin seeds, flax seeds and chia seeds). Women generally had whole wheat as their staple cereal as there were high factor loadings for chapathi and broken wheat, and clear negative factor loadings for plain white rice and ragi ball. Intake of other traditional, home-cooked breakfast dishes such as upma, poha, mandakki, shavige and dosa was high. Intake of Western-style wheat products (bun, white and brown bread, pasta/macaroni and spaghetti/noodles) was high. Intake of ready to eat breakfast cereals such as oats, wheat flakes, muesli, all bran flakes, cornflakes and chia seeds were high. Cooked vegetable sides included all the vegetables such as roots and tubers (potato, carrot, beetroot, radish, yam and tapioca) and other vegetable sides (ladyfinger or okra, gourds, pumpkin, capsicum, brinjal, beans, mushroom and mixed vegetable sides and sweetcorn). Traditional green leafy sides such as sambhar or drumstick were consumed. Other green sides such as cabbage and

cauliflower were consumed. Raw vegetables (cucumber, tomato, onion, carrot, runner beans and raw greens such as lettuce and spinach) were consumed as salads. Non-vegetarian foods included dishes of chicken, fish, mutton, organ meat, seafood and egg. This group also consumed salty traditional condiments such as pickles, papads, chutneys made with coconut and groundnut and onion, as well as western condiments such as tomato ketchup and instant soup. This group consumed more variety of all fried snacks listed (including medium calorie traditional savouries such as namkeens, chakli and high calorie savouries such as pakoda, samosa), chats, Chinese take away such as Manchurian, chips, savoury puffs and fast food such as pizzas and burgers. Sweets included chocolates, cakes and biscuits. Intake of all dairy products (curds, butter, ghee, cheese and paneer) were high. Seasonal foods such as mango, jackfruit, litchi and strawberry were high, including seasonal green beans and peas.

The second diet pattern is symbolic of a 'Rice-fried snacks-chicken-sweets' diet pattern. Here beverages with high factor loadings included tea, coffee, and buttermilk. Fruit mainly included banana (yelakki and robusta varieties). Cereal staples included ragi ball, plain white rice and all other rice preparations (sambhar rice), green leafy vegetable rice, spice seasoned/ flavoured rice and vegetable rice. This pattern also had high factor loadings for whole and split pulse preparations, traditional green leafy vegetable sides, more of chicken fry, chicken biriyani and chicken curry, high salt traditional condiments, medium and high calorie savoury fried snacks such as chakli, namkeen, samosa, pakoda and puff. Intake of traditional home-made sweets such as kesaribaath was high and added sugar was high because of tea and coffee

The third diet pattern is indicative of a 'Healthy, traditional vegetarian' pattern. There was a higher frequency of intake of milk, fermented dairy products (buttermilk & raita), therapeutic beverages (tender coconut water & electoral). Moderate variety of fruits (apple, pomegranate and sweetlime) and dried-fruits consumed were figs, prunes, apricots and dates and raisins were consumed. Women with high scores for this pattern also consumed almonds and other nuts and seeds. Staple cereal preparations included green leafy vegetable rice, curd rice, ragi ball, millet dishes (ragi dosa, ragi roti, ragi malt drink, ragi vermicelli and rotis made from other jowar, bajra and maize), whole

and split pulse preparations, raw vegetables, kosambiri, curd, ghee and seasonal fruits. This pattern showed lower consumption of western cereal products such as bun, bread, pasta and noodles. All non-vegetarian dishes including egg had negative factor loadings indicating that it was a 'clear vegetarian pattern'. This pattern also had negative factor loadings for fried foods (pakoda, samosa, shop bought puffs, chats), sweets (chocolates, cakes, milkshakes and ice-creams) and other fast foods (pizza, burger) indicating lower frequent intake.

The fourth diet pattern was suggestive of a 'Snacks, sweets and takeaway preference' pattern. Tea and coffee was consumed frequently by women in this pattern. Curds and ghee were frequently consumed. Cereal, pulse and vegetable sides lacked the diversity of patterns 1, 2 and 3 and included just curd rice and light cereal based tiffin dishes such as upma, poha, mandakki and semiya. Traditional salty condiments (pickles, papads and chutneys), added sugar through tea and coffee and all shop bought fried snacks (chakli, namkeen, pakoda, samosa, chips), chats and biscuits were more frequently consumed. Dried fruits, nuts and seeds and dishes of chicken, fish and egg had negative factor loadings, indicating infrequent intakes.

The fifth diet pattern was indicative of some elements of a Coastal-Karnataka based 'unpolished rice-cooked vegetables-fish' diet pattern. There was more frequent intake of unpolished rice and fermented cereal preparations such as idly, dosa, whole and split pulse preparations, all kinds of cooked vegetable sides of roots, tubers, cabbage, cauliflower, knol-khol, other vegetable sides included ladyfinger, gourds, pumpkin, capsicum, brinjal, beans, mushroom and mixed vegetable sides and sweetcorn. Fish intake had positive factor loadings reflecting coastal preferences. This pattern had lower frequent intake of milk, flavoured nutrient enriched beverage supplements, apple, fried savoury snacks, chocolates, fast foods such as pizza and burger and milkshakes and ice-creams.

7.8. Median frequency of intake of foods between the lowest and the highest quintiles of women's diet pattern scores for the five diet patterns

The median frequency of intake of key foods characteristic of each diet pattern showed convincing trends across quintiles of the diet pattern scores (table 7.7).

Table 7.7: Medians and IQR for weekly frequencies of intake of key foods according to quintiles of diet patterns scores (n=785)

Key foods exemplifying the diet pattern	Quintiles of women's diet pattern scores (units: weekly frequency of intake of foods)				
	1	2	3	4	5
High-diversity, urban Chapathi	1.0 (0.5, 2.0)	2.0 (1.0, 4.0)	3.0 (1.0, 7.0)	3.5 (2.0, 7.0)	7.0 (2.0, 7.0)
Flavoured sweetened beverages	0.25 (0.0, 1.0)	0.5 (0.0, 1.2)	0.7 (0.2, 2.0)	1.0 (0.1, 2.3)	2.0 (0.7, 5.1)
Other vegetables sides ^a	1.25 (0.5, 2.0)	2.25 (2.0, 4.0)	3.25 (2.0, 5.0)	3.75 (2.5, 5.2)	5.75 (3.5, 9.0)
Fruits ^b	0.5 (0.0, 1.25)	1.0 (0.25, 2.0)	1.5 (0.5, 3.0)	2.0 (0.75, 4.0)	3.0 (1.25, 7.5)
Seasonal fruits	5.75 (2.5, 10.0)	7.5 (3.5, 12.0)	9.0 (5.0, 14.0)	13.0 (7.5, 18.0)	16.5 (10.0, 22.5)
Raw vegetables ^c	1.75 (0.75, 3.0)	2.0 (1.0, 4.0)	3.0 (1.5, 5.0)	3.25 (1.5, 7.0)	5.5 (3.0, 10.0)
Sweet, cream & salted biscuits	0.25 (0.0, 1.0)	0.5 (0.0, 2.0)	1.0 (0.25, 3.0)	1.75 (0.0, 7.0)	2.25 (0.25, 7.0)
High calories savoury snacks ^d	0.75 (2.25, 1.5)	1.0 (0.25, 1.5)	1.25 (0.5, 2.25)	1.5 (0.75, 3.0)	2.0 (1.0, 3.75)
Ragi ball	7.0 (0.5, 7.0)	3.0 (0.0, 7.0)	0.5 (0.0, 7.0)	0.25 (0.0, 7.0)	0.25 (0.0, 4.0)
Plain boiled white rice					
Rice- fried snacks-chicken-sweets					
Tea & coffee	3.0 (0.0, 14.0)	7.0 (1.5, 14.0)	8.0 (0.0, 14.0)	14.0 (1.0, 14.0)	14.0 (7.0, 21.0)
Fermented dairy products ^e	1.0 (0.0, 3.1)	1.0 (0.0, 3.5)	2.0 (0.5, 4.0)	2.75 (1.0, 7.0)	5.0 (1.0, 8.0)
Banana ^f	2.0 (0.0, 4.0)	3.0 (1.0, 7.0)	3.0 (2.0, 7.0)	4.0 (1.0, 7.0)	7.0 (2.5, 7.0)
Plain boiled white rice	7.0 (3.0, 14.0)	14.0 (7.0, 14.0)	14.0 (14.0, 14.0)	14.0 (14.0, 21.0)	14.0 (14.0, 21.0)
Spice seasoned rice preparations ^g	1.25 (0.5, 2.0)	2.0 (1.0, 3.0)	3.0 (2.0, 4.0)	4.0 (2.0, 5.0)	4.0 (3.0, 6.0)
Chicken ^h	0.25 (0.0, 1.5)	0.5 (0.0, 1.5)	0.75 (0.0, 1.75)	1.0 (0.25, 2.0)	1.25 (0.5, 2.0)
Added sugar ⁱ	8.5 (3.0, 15.5)	14.0 (7.0, 17.0)	14.0 (7.0, 19.0)	15.0 (7.5, 21.0)	16.0 (14.0, 26.1)
Medium calories savoury snacks ^j	0.25 (0.0, 2.0)	0.25 (0.0, 1.25)	1.0 (0.0, 2.0)	1.0 (0.0, 3.0)	2.0 (0.5, 4.0)

Key foods exemplifying the diet pattern	Quintiles of women's diet pattern scores (units: weekly frequency of intake of foods)				
	1	2	3	4	5
Fast food ^k	0.25 (0.0, 0.5)	0.0 (0.0, 0.25)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)
Dried fruits ^l	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)
Healthy, traditional vegetarian					
Fermented dairy products ^e	1.0 (0.25, 2.5)	1.0 (0.25, 4.0)	1.5 (0.25, 4.0)	3.0 (1.0, 7.0)	6.0 (1.0, 8.0)
Ragi ball	0.0 (0.0, 3.0)	0.75 (0.0, 7.0)	3.0 (0.0, 7.0)	3.0 (0.0, 7.0)	4.0 (0.5, 7.0)
Traditional whole and split pulse preparations	4.0 (3.0, 7.5)	4.0 (2.5, 7.0)	5.0 (3.0, 7.5)	7.0 (4.0, 9.0)	6.5 (4.5, 10.5)
Traditional style GLV sides ^m	2.25 (1.25, 4.0)	3.0 (2.0, 4.0)	3.0 (2.0, 4.0)	3.0 (2.0, 4.5)	3.5 (2.0, 5.0)
Raw vegetables ^c	2.0 (1.0, 4.0)	2.0 (1.0, 4.0)	2.0 (1.0, 4.5)	3.0 (1.5, 6.5)	5.0 (2.2, 9.0)
Traditional, home-made cereal based sweets ⁿ	0.5 (0.25, 0.75)	0.25 (0.0, 0.75)	0.25 (0.0, 0.75)	0.25 (0.0, 0.5)	0.25 (0.0, 0.5)
^oTraditional shop bought sweets	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 1.0)	0.0 (0.0, 1.0)	0.0 (0.0, 1.0)
^kFast food	0.0 (0.0, 0.5)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.25)
Snacks, sweets and takeaway preference					
Tea and coffee	7.0 (0.0, 14.0)	7.25 (0.0, 14.0)	14.0 (2.0, 14.0)	14.0 (2.5, 14.5)	14.0 (3.0, 21.0)
^pCereal savouries	1.0 (0.25, 2.0)	1.0 (0.25, 2.0)	1.0 (0.75, 2.0)	1.5 (1.0, 2.5)	2.0 (1.0, 3.0)
Pickles, papads, chutneys and chutney powders	4.0 (2.0, 6.5)	3.5 (2.0, 9.0)	4.5 (2.5, 7.5)	8.0 (4.0, 11.5)	9.0 (6.5, 9.5)
High calories savoury snacks	1.0 (0.5, 2.0)	1.0 (0.25, 2.0)	1.0 (0.5, 2.0)	1.25 (0.5, 2.5)	1.5 (0.5, 3.5)
Sweet, cream & salted biscuits	0.5 (0.0, 2.0)	0.75 (0.0, 2.5)	0.5 (0.0, 2.0)	1.0 (0.0, 5.5)	2.0 (0.25, 7.0)
Added sugar ⁱ	10.5 (6.5, 16.5)	14.0 (6.0, 19.0)	14.0 (7.0, 17.5)	14.7 (7.0, 21.0)	16.0 (9.0, 22.0)
Chicken preparations	2.0 (1.0, 2.0)	1.25 (0.5, 2.0)	1.0 (0.25, 1.5)	0.5 (0.0, 1.0)	0.0 (0.0, 0.5)
Unpolished rice-fish-vegetables					
Dosa and masala dosa	1.0 (0.5, 2.0)	1.0 (0.5, 1.25)	1.0 (0.75, 1.5)	1.25 (1.0, 2.0)	2.0 (1.0, 3.0)
Traditional whole and split pulse preparations	4.0 (2.5, 7.0)	5.0 (3.0, 8.0)	5.0 (3.0, 7.0)	5.5 (3.5, 8.0)	8.0 (5.0, 11.0)
^qFish	0.0 (0.0, 0.25)	0.0 (0.0, 0.25)	0.0 (0.0, 0.5)	0.0 (0.0, 0.5)	0.25 (0.0, 1.5)
^rUnpolished rice	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)
Cows milk	7.0 (0.0, 7.0)	1.0 (0.0, 7.0)	0.0 (0.0, 3.0)	0.0 (0.0, 2.0)	0.0 (0.0, 1.0)
Medium calories savoury snacks	2.0 (0.2, 4.0)	1.25 (0.1, 2.5)	1.0 (0.0, 2.0)	0.5 (0.0, 2.0)	0.5 (0.0, 2.0)

Lighter shading indicates increasing consumption across quintiles, Darker shadings indicate decreasing consumption across quintiles

^a Other vegetables sides include lady's finger, gourds, pumpkin, capsicum, brinjal, beans, mushroom, multiveg saagu; ^b Fruits include all fruits except apple, yelakki banana, robusta banana, sweetlime, guava, pomegranate and green grapes; ^c Raw vegetables include cucumber, tomato, onion, carrot, radish, runner beans and raw greens; ^d High calories savoury snacks include pakoda/bonda/bhajji/samosa; ^e Fermented dairy products include buttermilk & raitha; ^f Banana include yelakki and robusta varieties; ^g Spice seasoned/flavoured rice preparations include tamarind, tomato, lemon, ghee, jeera, veg rice include pulao and bisibelebaath; ^h Chicken Preparations include fry and curry/ sambhar; ⁱ Added sugar include sugar in tea, coffee, milk, fruit juice, jam, honey and jaggery; ^j Medium calories savoury snacks include namkeen and chakli; ^k Fast foods include veg and non-veg pizza and burger; ^l Dried fruits include figs, prunes and apricots; ^m Traditional style GLV sides include GLV sambhar, GLV palya and drumstick palya; ⁿ Traditional, home-made cereal based sweets such as kesariabaath, holige and kheer; ^o Traditional shop bought fried sweets include khoa based sweets like barfi, pedha, jamoon, laddoo, halwa and other sweets; ^p Cereal savouries include upma / semolina and poha / beaten rice and mandakki / puffed rice and semiya / vermicelli; ^q Fish include fry, curry, cutlet, dried fish/ dried seafood/ prawn, crab & shellfish; ^r Unpolished rice include red and brown rice.

7.9. Associations between population characteristics and women's diet patterns scores

Table 7.8 describes the univariate regression analysis of various population characteristics as predictors of women's diet pattern scores (effect size not shown). Women from Cloudnine hospital had higher scores on the first, third, fourth and fifth patterns, while women from Baptist hospital had higher scores on the second pattern. Hospital type was strongly associated with women's diet pattern scores. Age and BMI were used as continuous variables and gravidity, PCOS and hypothyroid status, and family history of T2DM as categorical variables. For categorical variables, primi-gravid women, no PCOS and hypothyroid status and no family history of T2DM were used as the reference group. Older women were more adherent to the first and fifth diet patterns. To indicate the effect size, with every decade (10 years) increase in age, there was a 0.47 SD increase of the first diet pattern scores, and with every decade increase in age, there was a 0.61 SD decrease in diet pattern 2 scores. On the other hand, younger women were more adherent to the second diet pattern. Lower BMI was associated with higher scores for the second and third diet patterns, and higher BMI was associated with higher scores for the fifth diet pattern. For instance, every unit increase in BMI was associated with a decrease of 0.061 SD scores of the third diet pattern. Primi-gravid women had higher scores for the fourth diet pattern and multi-gravid women had higher scores for the second and fifth diet patterns. Women with PCOS status had higher scores for the first and fifth diet patterns and women without PCOS had higher scores for the second diet pattern. Women with thyroid

problems had higher scores for the first diet pattern. And women without thyroid problems showed higher scores for the second diet pattern. Women with a family history of T2DM had higher scores for the second diet pattern. Women without a T2DM family history showed higher scores for the first diet pattern. To summarise, age, BMI, gravidity, PCOS and hypothyroid status and family history of T2DM were associated with women's diet pattern scores. For comparing diet pattern scores across religions, Hindu women were used as the reference group. Jain, Muslim and Christian women had higher diet pattern scores for the first pattern. Hindu women had higher scores for the second pattern. Jain women, followed by Hindu women, had higher scores for the third pattern, compared to Muslim and Christian women. Hindu and Jain women had higher scores for the fourth pattern. Christian women, followed by Hindu women, had higher scores for the fifth pattern. In the regression analysis of education level as a predictor of diet patterns scores, the education level of high school and less was used as the reference group. Level of education was positively associated with the first pattern. On the other hand, education level showed a negative association with the second pattern, indicating that women educated to the level of high school and less were more adherent to this pattern than graduates and post-graduate women. Income was positively associated with the first and fifth patterns, and negatively associated with the second pattern. SLI was positively associated with the first and third patterns. SLI was not associated with the second, fourth and fifth patterns. Urban residence was associated with higher scores for the first and fifth patterns, and lower scores for the second and third patterns. Joint family type was associated with higher scores for the second and third patterns.

In summary, the first pattern was an affluent diet pattern associated with higher income and SLI and urban residence. The second pattern was associated with lower income and rural residence. The third pattern was associated with higher SLI, rural residence and a joint family type. The fourth pattern was associated with higher income. The fifth pattern was associated with higher income and urban residence (table 7.8).

Table 7.8: Univariate regression analysis of population characteristics as predictors of women's diet pattern scores (n=785*)

Predictors: Population characteristics	N	Diet pattern score – Mean (SD)									
		1		2		3		4		5	
		High-diversity, urban		Rice-fried snacks- chicken-sweets		Healthy, traditional vegetarian		Snacks, sweets and takeaway preference		Unpolished rice-fish- vegetables	
		Mean (SD)	p	Mean (SD)	p	Mean (SD)	p	Mean (SD)	p	Mean (SD)	p
Hospital type:											
Baptist	663	-0.09 (0.93)	<0.001	0.17 (0.91)	<0.001	-0.07 (0.92)	0.001	-0.07 (0.92)	<0.001	-0.03 (0.95)	0.009
Cloudnine	122	0.53 (1.14)		-0.94 (0.90)		0.42 (1.27)		0.42 (1.24)		0.21 (1.18)	
Age groups (in years):											
< 22 years	114	-0.29 (0.97)	<0.001	0.37 (0.83)	<0.001	-0.09 (0.85)	0.365	-0.05 (0.88)	0.820	-0.46 (0.94)	<0.001
22 - years	250	-0.11 (1.00)		0.17 (0.93)		-0.02 (0.95)		-0.01 (1.00)		-0.15(0.91)	
26 - 30 years	248	0.01 (0.89)		-0.08 (1.00)		-0.01 (0.98)		0.08 (0.99)		0.04 (0.98)	
>30 years	173	0.34 (1.06)		-0.38 (1.03)		0.10 (1.16)		-0.07 (1.05)		0.47 (0.97)	
BMI* (in Kg/m²):											
<18.5	80	0.06 (1.05)	0.812	0.39 (1.10)	<0.001	0.13 (0.87)	0.004	-0.17 (1.06)	0.273	-0.30 (0.99)	<0.001
18.5 - 24.9	412	-0.01 (1.03)		0.10 (0.97)		0.06 (1.04)		-0.01 (1.01)		-0.06 (1.03)	
25 - 29.9	201	0.01 (0.86)		-0.25 (0.91)		-0.15 (0.93)		0.11 (0.97)		0.09 (0.84)	
>30	69	0.01(1.07)		-0.29 (1.06)		-0.06 (0.87)		-0.05 (0.90)		0.43 (1.05)	
Gravida:											
Primigravida	415	-0.05 (0.99)	0.060	-0.06 (1.01)	0.048	-0.01 (1.00)	0.488	0.07 (0.97)	0.041	-0.14 (0.98)	<0.001
Multigravida	370	0.06 (1.00)		0.06 (0.98)		0.01 (0.99)		-0.08 (1.01)		0.15 (0.98)	
T2DM family history from first degree relatives:											
No	536	-0.06 (0.95)	0.007	1.10 (0.99)	<0.001	0.01(0.96)	0.366	0.03 (0.94)	0.150	-0.03 (0.93)	0.139
Yes	249	0.13 (1.07)		-0.23 (0.98)		-0.03 (1.06)		-0.07 (1.11)		0.07 (1.12)	
PCOS diagnosis*:											
No	701	-0.03 (0.98)	0.002	0.04 (0.98)	<0.001	-0.02 (0.98)	0.099	0.01 (0.99)	0.471	-0.01 (0.98)	0.137
Yes	83	0.33 (1.06)		-0.38 (1.04)		0.22 (1.06)		-0.08 (1.03)		0.13 (1.08)	
Hypothyroid diagnosis*:											
No	641	-0.03 (0.97)	0.002	0.04 (0.98)	0.003	-0.01 (0.97)	0.391	-0.01 (0.99)	0.416	0.11 (0.96)	0.491
Yes	142	0.17 (1.10)		-0.21 (1.05)		0.08 (1.10)		0.06 (1.02)		-0.04 (1.14)	
Religion*:											

Predictors: Population characteristics	N	Diet pattern score – Mean (SD)									
		1		2		3		4		5	
		High-diversity, urban		Rice-fried snacks- chicken-sweets		Healthy, traditional vegetarian		Snacks, sweets and takeaway preference		Unpolished rice-fish- vegetables	
		Mean (SD)	p	Mean (SD)	p	Mean (SD)	p	Mean (SD)	p	Mean (SD)	p
Hindu	607	-0.08 (0.95)		0.09 (1.00)		0.17 (0.93)		0.11 (0.93)		-0.01 (0.96)	
Christian	111	0.10 (0.98)	0.060	-0.23 (0.74)	0.019	-0.74 (0.81)	<0.001	-0.34 (0.94)	<0.001	0.19 (0.97)	0.058
Muslim	47	0.56 (1.24)	<0.001	-0.33 (1.04)	0.033	-0.77 (0.96)	<0.001	-0.98 (1.11)	<0.001	-0.27 (1.35)	0.070
Jain	11	0.58 (0.71)	0.027	-1.58 (0.53)	<0.001	0.91 (0.65)	0.065	1.10 (0.43)	<0.001	-0.59 (0.77)	0.059
Educational attainment:											
High school and less	117	-0.15 (1.03)		0.37 (0.94)		-0.14 (0.93)		-0.06 (1.03)		0.01 (0.91)	
Intermediate & Pre-university	137	-0.25 (0.89)	0.413	0.31 (0.83)	0.548	-0.04 (0.85)	0.584	0.04 (0.82)	0.379	-0.13 (1.01)	0.275
Graduate	312	0.04 (0.98)	0.062	0.04 (0.97)	0.001	-0.05 (0.98)	0.809	-0.01 (0.95)	0.590	0.002 (0.98)	0.952
Postgraduate	219	0.17 (1.02)	0.004	-0.46 (0.98)	<0.001	0.18 (1.11)	0.070	0.02 (1.13)	0.388	0.07 (1.05)	0.460
Income categories*:											
<25,000	289	-0.27 (0.88)	<0.001	0.30 (0.83)	<0.001	-0.02 (0.84)	0.117	0.04 (0.82)	0.225	-0.06 (0.93)	0.009
25,000 -50,000	180	0.05 (0.95)		-0.001 (0.92)		-0.08 (0.93)		-0.01 (1.01)		-0.006 (0.92)	
50,000- 100000	109	0.15 (1.02)		-0.56 (0.94)		0.008 (1.20)		0.06 (1.30)		0.04 (1.20)	
≥100000	59	0.63 (1.04)		-1.01 (0.79)		0.30 (1.25)		0.22 (1.10)		0.33 (1.01)	
SLI score:											
Low	1	-0.10	0.003	0.26	0.776	-1.65	<0.001	-0.97	0.053	-1.86	0.163
Medium	31	-0.25 (0.87)		0.04 (0.99)		-0.19(1.00)		0.05 (1.07)		0.03 (0.88)	
High	753	0.01 (1.00)		-0.002 (1.00)		0.01 (0.99)		-0.0008 (0.99)		0.001 (1.00)	
Area of residence*:											
Urban	539	0.13 (1.01)	<0.001	-0.22 (0.97)	<0.001	-0.09 (1.05)	<0.001	0.03 (1.08)	0.420	0.04 (1.04)	0.025
Rural	233	-0.30 (0.90)		0.51 (0.87)		0.23 (0.82)		-0.06 (0.80)		-0.12 (0.87)	
Family type											
Nuclear	429	0.04 (0.96)	0.120	-0.14 (0.99)	<0.001	-0.04 (0.96)	0.069	0.01 (1.01)	0.904	0.03 (1.02)	0.334
Joint	356	-0.05 (1.04)		1.17 (0.97)		0.05 (1.03)		-0.02 (0.98)		-0.04 (0.96)	
Levels of light walking:											

Predictors: Population characteristics	N	Diet pattern score - Mean (SD)									
		1		2		3		4		5	
		High-diversity, urban		Rice-fried snacks- chicken-sweets		Healthy, traditional vegetarian		Snacks, sweets and takeaway preference		Unpolished rice-fish- vegetables	
		Mean (SD)	p	Mean (SD)	p	Mean (SD)	p	Mean (SD)	p	Mean (SD)	p
No walking	374	-0.09 (0.98)		0.04 (1.01)		0.001 (0.92)		-0.05 (1.02)		0.06 (0.96)	
Upto 150	259	0.07 (0.99)	0.157	-0.05 (0.98)	0.283	-0.04 (1.04)	0.284	0.11 (1.01)	0.037	-0.07 (1.07)	0.113
minutes/ week											
Above 150	152	0.10 (1.02)		-0.02 (0.98)		0.06 (1.10)		-0.04 (0.91)		-0.02 (0.92)	
minutes/ week											
Screen time:											
Below 4 hrs/day	561	0.01 (1.04)	0.626	0.10 (0.99)	<0.001	0.05 (1.01)	0.297	-0.06 (0.99)	0.021	0.01 (0.99)	0.526
Above 4 hrs/day	224	-0.02 (0.88)		-0.26 (0.96)		0.01 (0.97)		0.15 (1.00)		-0.03 (1.02)	
*n missing: BMI=23; PCOS diagnosis=1; Hypothyroid diagnosis=2; Religion=9; Income=148; Area of residence=13; text in red = reference group in logistic regression analysis.											

7.10. Association between women's peri-conceptional diet patterns and GDM

In the univariate PCA models of 68 food groups, none of the diet patterns showed any association with GDM risk (table 7.9).

7.11. Reviewing the concept diagram

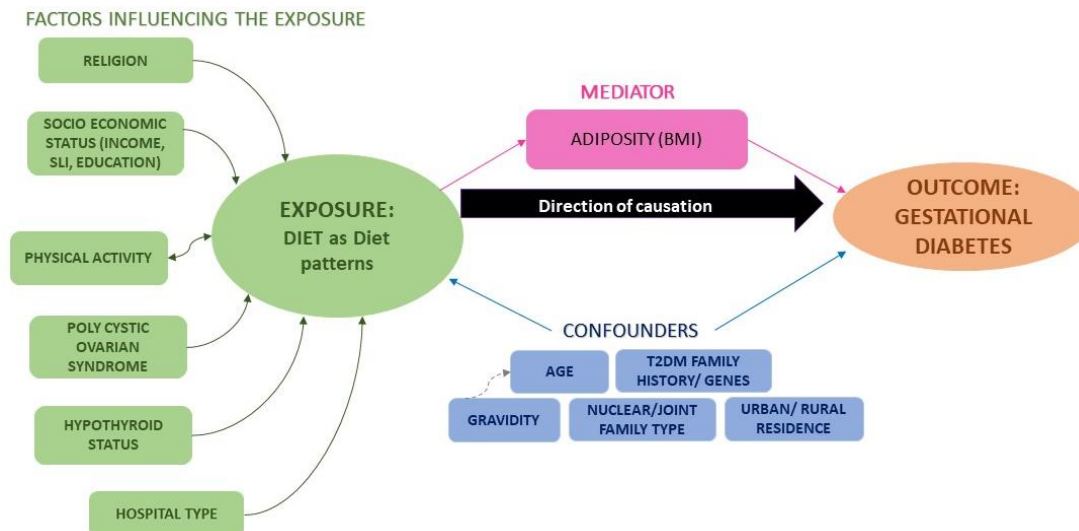
In chapter 5, I showed that age, BMI, gravidity, area of residence, family type and family history of T2DM were associated with GDM risk. In this chapter I have shown that age, BMI, gravidity, family history of T2DM, area of residence and family type were associated with the diet patterns in univariate models.

In summary age, BMI, family history of T2DM, area of residence and family type were associated with both the exposure and the outcome. While age, gravidity, area of residence and family type may be considered confounders, BMI may be a potential mediator (in the 'diet-GDM causal pathway', see figure 7.5, page 210). As demonstrated earlier, (Chapter 5, page 156) gravidity was associated with GDM risk through increasing age. In the next section, I will test the final diet pattern-GDM associations, with statistical adjustment for the confounders and the mediator in multivariate regression analysis.

Table 7.9: Univariate regression analysis of women's diet pattern scores as predictors of GDM (n=714*)

GDM	N	Diet pattern score - Mean (SD)									
		1		2		3		4		5	
		High-diversity, urban		Rice-fried snacks-chicken-sweets		Healthy, traditional vegetarian		Snacks, sweets and takeaway preference		Unpolished rice-fish-vegetables	
		Mean (SD)	p	Mean (SD)	p	Mean (SD)	p	Mean (SD)	p	Mean (SD)	p
No	557	0.01 (1.01)	0.36	0.04 (0.99)	0.19	0.01 (0.96)	0.40	0.04 (0.98)	0.27	-0.02 (1.00)	0.11
Yes	157	0.06 (0.89)		-0.08 (0.96)		-0.06 (1.12)		-0.04 (1.06)		0.11 (1.02)	

*n missing: glucose tolerance = 81; text in **red** indicates reference group in regression analysis (GDM: **0 = no**, 1 = yes)

Figure 7.5: Concept diagram exploring causal associations between diet and gestational diabetes mellitus, drawn from chapter findings

7.12. Univariate and multivariate logistic regression models of women's diet pattern scores, confounders and mediator as predictors of GDM

Table 7.10 shows the four regression analyses that I carried out, starting with the univariate models. The first multivariate model was adjusted for confounders selected by the 'data-driven' approach (only those significantly related to both the exposures and outcome in my data) and included all 714 women who completed a 75-gram OGTT, 35 women who had a GCT, and 2 women with fasting and postprandial blood glucose tests (model 1). The second model was a sensitivity analysis consisting of the 677 women who had 75-gram OGTT results only (model 2). This was carried out because a 75-gram GTT is considered a more robust GDM screening method than the GCT (WHO, 2013), and to explore if excluding cases diagnosed by other methods would change any observed findings. The third model used the full sample (N=714) and was adjusted for confounders selected using the '*a priori*' approach (all known potential confounders based on previous literature) (model 3). All the multivariate analyses included two models, with and without adjustment for BMI (figure 7.5).

Higher scores of the high diversity urban (HDU) pattern were associated with a lower risk of GDM; the association was statistically significant at the traditional level for one model, model 3 (aOR 0.80, 95% CI: 0.64, 0.99, $p=0.04$). After adjusting for multiple testing, using the Bonferroni correction, which mandated a significance threshold of $p<0.01$ ($0.05/5$), none of these associations was statistically significant. When BMI was added to all the models, the associations between the HDU pattern and GDM were weakened, suggesting that any relationship may be mediated by BMI. There was no evidence that the other four diet patterns were related to GDM risk.

Table 7.10: Multivariate logistic regression models of women's diet pattern scores as predictors of GDM

DP scores (SD)	GDM: 0 = no, 1 = yes																																	
	Univariate model				Multivariate model ¹						Multivariate model ²						Multivariate model ³																	
	-				Model without BMI			Model with BMI			Model without BMI			Model with BMI			Model without BMI			Model with BMI														
	n=701				n=678						n=664						n=641						n=700						n=677					
	OR	95% C.I.	p		OR	95% C.I.	p	OR	95% C.I.	p	OR	95% C.I.	p	OR	95% C.I.	p	OR	95% C.I.	p	OR	95% C.I.	p	OR	95% C.I.	p									
1	0.90	0.75, 1.08	0.29		0.83	0.68, 1.06	0.07	0.87	0.71, 1.07	0.19	0.65	0.65, 1.01	0.04	0.84	0.67, 1.05	0.12	0.80	0.64, 0.99	0.04	0.84	0.67, 1.05	0.12												
2	0.87	0.72, 1.05	0.15		0.99	0.81, 1.22	0.96	1.06	0.86, 1.32	0.56	0.76	0.76, 1.18	0.63	1.01	0.81, 1.27	0.92	0.89	0.71, 1.11	0.32	0.96	0.76, 1.21	0.75												
3	0.93	0.77, 1.12	0.45		0.94	0.78, 1.14	0.53	0.97	0.80, 1.18	0.74	0.80	0.80, 1.20	0.83	1.01	0.82, 1.25	0.92	0.95	0.78, 1.16	0.65	0.98	0.80, 1.21	0.90												
4	0.90	0.75, 1.08	0.27		0.90	0.75, 1.09	0.28	0.88	0.72, 1.07	0.20	0.73	0.73, 1.09	0.27	0.88	0.71, 1.08	0.21	0.94	0.77, 1.14	0.55	0.90	0.74, 1.11	0.34												
5	1.26	0.96, 1.40	0.10		1.07	0.88, 1.31	0.48	0.97	0.78, 1.19	0.74	0.92	0.92, 1.42	0.23	1.04	0.83, 1.30	0.75	1.02	0.28, 1.25	0.84	0.94	0.75, 1.16	0.55												

DP 1 - High-diversity, urban; DP 2 - Rice-fried snacks-chicken-sweets; DP 3 - Healthy, traditional vegetarian; DP 4 - Snacks, sweets & takeaway preference
 DP 5 - Unpolished rice-fish-veg.

Used as reference group in logistic regression analysis

¹ Model adjusted for data-driven confounders including woman's age, family history of T2DM (no/yes), area of residence (urban/rural) & family type (nuclear/joint).

² Model for sensitivity analysis, limited to women who had a full OGTT, adjusted for the data-driven confounders including woman's age, family history of T2DM (no/yes), area of residence (urban/rural) & family type (nuclear/joint).

³ Model adjusted for *a priori* confounders including woman's age, gravidity, PCOS status (no/yes), area of residence (urban/ rural), family type (nuclear and joint), family history of T2DM (no/yes), use of nutrient supplements (Calcium-vitamin D, B12, iron, folic acid and energy-protein), and physical activity (weekly light walking) and SES measures (SLI score, education & occupation levels).

7.13. Discussion

7.13.1. Summary of findings

Five distinct diet patterns were derived from PCA, namely, the high-diversity urban pattern, the rice-fried snacks-chicken-sweets pattern, the healthy traditional vegetarian pattern, the snacks-sweets-takeaway preference pattern and the unpolished rice-fish-vegetables pattern. Higher scores for the high-diversity urban (HDU) pattern were associated with a lower prevalence of GDM in one model, after adjusting for a priori confounders determined from the literature, at the traditional ($p < 0.05$) level. The strength of this association was reduced after adjusting for BMI suggesting that any effect of the HDU diet pattern on GDM risk may be mediated by BMI. The association was non-significant in all other models, and after applying the Bonferroni correction, suggesting that it may be a chance finding. The other diet patterns did not show any association with GDM, across all the models.

7.13.2. Dietary patterns relate to the population characteristics and real life settings

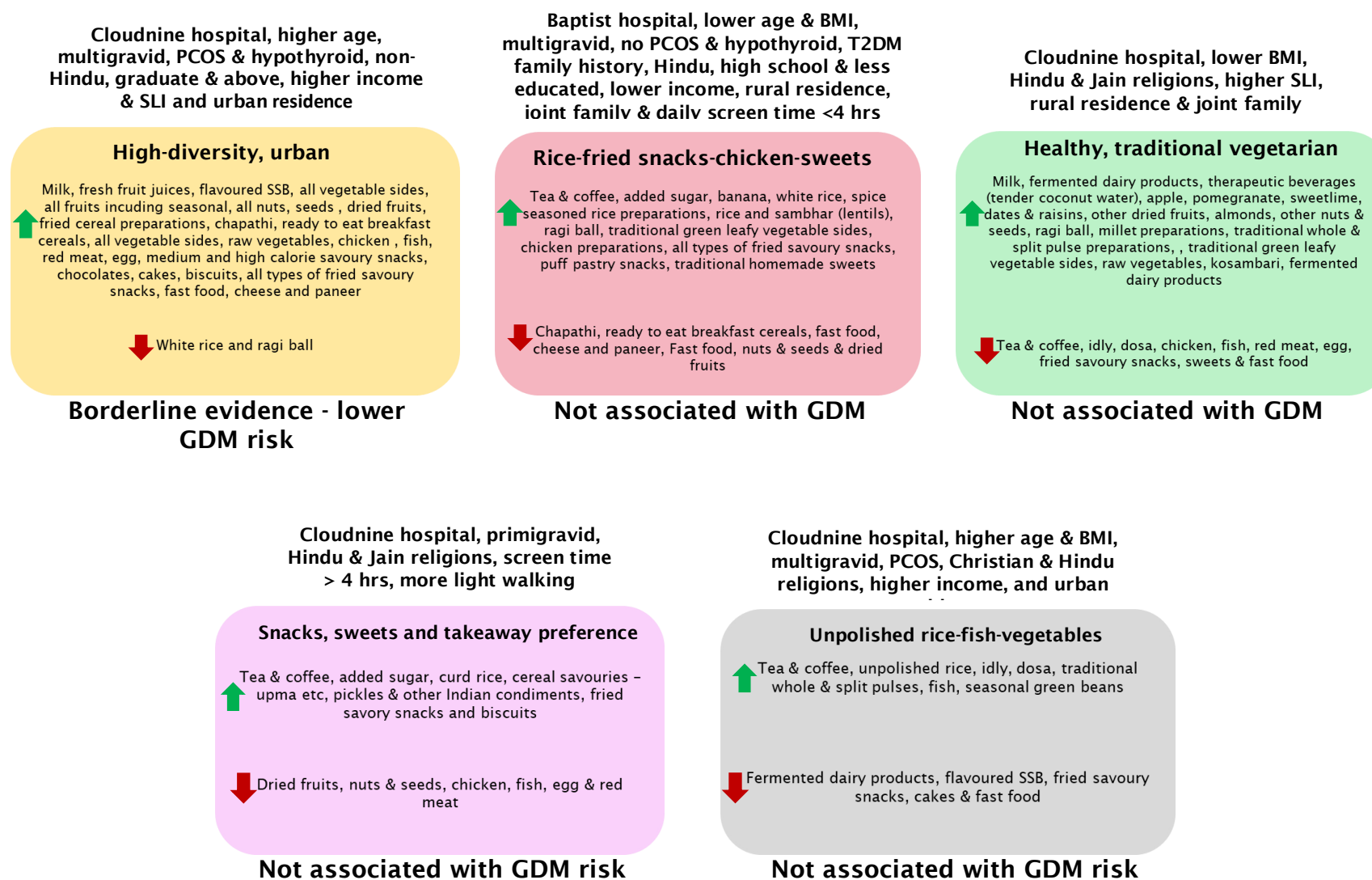
The five diet patterns were distinct from each other and robust because: a) Similar diet patterns appeared in the PCA of 205 foods and the PCA of 68 food groups b) There were strong correlations between each pattern of PCA of 205 foods and 68 food groups c) The pattern discriminating foods did not change. For instance, in both PCAs, patterns 1, 2 and 3 retained wheat, rice and ragi as staple cereals respectively.

Each of these diet patterns also contrasted well in reflecting differences in population characteristics, especially BMI and SES. The first diet pattern, that explained 8.5 per cent of the variance in the sample was associated with the women attending Cloudnine hospital, being older, multigravid, having a PCOS and hypothyroid diagnosis and not having a family history of T2DM. This pattern was also associated with women being non-Hindu, educated to graduate level or above, having higher incomes, high SLI and urban residence. The foods making up this pattern are usually available in urban metropolitan parts of Bangalore. A variety of nuts and seeds, dried fruits and fruits, which are expensive, were a part of this diet pattern. Most nuts and dried fruits cost

approximately INR 1500 per kilogram (Hopcoms, 2019) currently in India. Most fruits are expensive and this is the only pattern in which a variety of fruits were consumed. For instance, pomegranates cost *INR 128 per kilogram* and ripe mangoes cost *INR 100 per fruit in all seasons* (Hopcoms, 2019). Good quality meat is also expensive as one kilogram of fish and chicken cost *about INR 350 and mutton costs INR 500 per kilogram* (National Chicken Council, India 2019). This pattern included healthy foods such as milk, fruits, dried fruits, cooked vegetables and greens, whole wheat chapathis as their staple cereal food as well as unhealthy fast foods such as sugar sweetened beverages, pizzas, burgers, shop bought chips, sweets, cakes and biscuits (figure 7.6). The second diet pattern was associated with women being younger, thinner, multigravid, not having PCOS or thyroid problems, having a family history of T2DM and attending Baptist Hospital. Additionally, it was associated with being Hindu, educated to the level of high school and less, having a lower income, being from joint family, living in a rural area and having a daily screen time lower than 4 hours. Inexpensive foods such as bananas, ragi balls, white rice and fried savoury snacks that were characteristic of this diet pattern relate to the low income and SLI. In government led subsidised ration shops, *low quality rice is as cheap as INR 2 per kilogram* (Sekher et al. 2017) and *good quality rice prices start from INR 53 per kilogram* (Agriwatch, 2019), which is sufficient for a family of four for a week. If a family has mostly rice, dal, basic vegetables (including potato, tomato and onion) and bananas, similar to this diet pattern, they can easily manage their household food budget *within INR 5000 per month* (figure 7.6).

The third diet pattern was associated with attending Cloudnine hospital, lower BMI, Hindu and Jain religions, higher SLI, rural residence and living in a joint family. This pattern may be explained as the 'Vegetarian-Indian equivalent' of the popular Mediterranean diet pattern in some ways to a western audience who may not be aware of the elements of an Indian diet. Nutrient-wise, this pattern was high in fibre, vitamins, minerals and antioxidants and food-wise, rich on wholegrains, legumes and lentils, nuts, seeds, fresh fruit and dried fruit, raw vegetables, yogurt, milk and green leafy vegetables. There was less consumption of fried and fast food, sugar, meat, and less eating out and focussed on traditional-home-cooked-foods (figure 7.6).

Figure 7.6: Summary diagram of peri-conceptional diet patterns and their associations with population characteristics



The fourth diet pattern was more associated with attending Cloudnine hospital, being primigravid, belonging to Hindu and Jain religions, being more active and having a high daily screen time.

The second and fourth patterns were relatively unhealthy compared to patterns 1, 3 and 5 but differed in the fact that the second pattern was associated with a lower income and SLI, rural residence and a joint family. On the other hand, the fourth pattern was associated with a higher SLI, urban residence and a nuclear family type (figure 7.6).

The fifth diet pattern was associated with attending Cloudnine hospital, being older, having a higher BMI, being multigravid, having PCOS, being Christian and Hindu, having a higher income and an urban residence (figure 7.6).

7.13.3. Plausibility of the high-diversity urban pattern association with lower GDM risk

Taking a balanced overview of my findings, my study did not provide strong or incontrovertible evidence that any particular diet pattern is 'protective' or 'risky' in relation to GDM. However, there was some evidence that the high-diversity urban pattern might be associated with a lower risk of GDM, and this is plausible when taken alongside other published studies of diet and GDM.

Existing evidence suggests that women who develop GDM have pre-pregnancy β - cell dysfunction and insulin resistance and therefore a reduced ability to adjust to the metabolic challenges presented in pregnancy (Buchanan & Xiang, 2005). Adherence to a diet in the peri-conceptional period that contains healthful components from the high-diversity urban pattern may be helpful in lowering GDM risk, by abating some metabolic pre-dispositions (Tobias 2012).

Healthful components from the HDU diet pattern include a *high intake of a variety of* micronutrient rich foods such as wholegrain cereals, legumes and pulses, fruit and vegetables, green leafy vegetables, nuts and seeds, dried fruits, milk and dairy products, variety of non- vegetarian dishes from egg, poultry and meat (details, section 7.7). Wholegrain cereals have been associated with lower GDM risk (Zhang et al., 2006b and Brand-Miller et al., 2003), due to their low glycaemic index owing to high insoluble fibre content which slows glucose absorption (de Munter et al., 2007). In pattern 1, the

median frequency of chapathi intake increased while that of white rice decreased from the lowest to highest quintiles of the pattern scores (table 7.7). The harmful effect of *white rice* in Asian populations, relating greater intake to a higher T2DM risk is known (Villegas et al., 2007 & Nanri et al., 2010) due to its high glycaemic index (Sugiyama et al., 2003; Mohan et al., 2009 & Salmerón et al., 1997).

Legumes and pulses are a source of different amino acids essential for growth and development (Minocha et al., 2017). Fruits and vegetables provide dietary fibre and polyphenolic antioxidants (Plows et al., 2018). Antioxidants may scavenge free radicals and AGEs from unhealthy components (fried and fast foods, sweets, SSB and red meat) of the HDU pattern (Plows et al., 2018). Nitrates from greens increase thermogenesis, oxygen consumption, and β -oxidation of adipocytes leading to less adiposity (Slavin & Lloyd, 2012). Magnesium-rich foods, such as vegetables, nuts and legumes can reduce insulin resistance through improved cell-signalling (Barbagallo et al., 2003). Dietary fibre (from fruits, vegetables, whole grain cereals and legumes) delays gastric emptying, which slows down glucose absorption and reduces plasma insulin levels (Chandalia et al., 2000). Although red and processed meat intake has been associated with a higher risk of GDM and T2DM (Pan et al., 2011) in most western studies, unprocessed meat has not been associated with a higher risk as suggested by a systematic review (Micha et al., 2010). There is no robust Indian study yet, that links meat intake to higher risk of T2DM or GDM. In India although meat intake is slowly rising due to economic transition (Popkin, 2002), actual intake is still low (5 kg per capita annually) unlike most developed countries where per capita annual meat intake is greater than 120 kgs (OECD-FAO, 2014). Also 20-42% of Indians are vegetarians due to the climate, geography, religion, and food culture (Devi et al., 2014b) similar to my study, where 50 percent of the women were vegetarian.

7.13.4. What do other studies of dietary patterns and GDM in the West, South Asia and India show?

Dietary pattern studies in developed countries (USA, Iceland and Australia) derived clear healthy and unhealthy diet patterns, whereas studies in developing countries (China and Brazil) derived patterns that were not clearly healthy or unhealthy (described in 1.5.4, page 25).

Studies in high-income Asian countries such as Singapore have found diet patterns which cannot, unlike the Western studies, be distinctly defined as 'healthy' or 'unhealthy'. The GUSTO study found that a 'vegetable-fruit-rice' based diet pattern was associated with higher fasting plasma glucose levels and a 'seafood-noodle based diet' was inversely associated with GDM risk (De Seymour et al., 2016). Noodles have a lower glycaemic index than white rice (De Seymour et al., 2016). This was similar to my study where, in the HDU pattern, women consumed more chapathi than rice. Studies in upper middle-income countries such as Brazil (Nascimento et. al., 2016) have identified the traditional, western and mixed patterns, but found no difference in GDM risk. Similarly, Sedaghat et. al. (2017) in Iran identified prudent and western diet patterns, but found no association between the prudent pattern and GDM risk, although women above the 50th centile of the western diet pattern (high sugar, salt, fat, potatoes, eggs and meat) had a higher risk of GDM (Sedaghat et. al., 2017) (details, pages 28 - 34).

In India, no study has explored diet patterns and GDM risk. However, diet patterns in association with other health outcomes suggest that the diets in India are largely vegetarian (high in fruit, vegetables and pulses) with additional patterns high on sweets, snacks, and meat (Misra et al., 2011). Dietary pattern analysis is a holistic method that takes into account the whole diet, however globally, the results are inconsistent across different geographical regions due to the heterogeneity of diet composition across the globe (Green et al., 2016). There are also in-country differences. For instance, in Karnataka, rice and ragi are staples in the south while wheat and jowar are staples in the north (Devdas et al., 1999). Most Indian studies have not identified clear healthy/unhealthy diet patterns due to low awareness among people about healthy/unhealthy foods (Green et al., 2016).

Common characteristics of healthy diet pattern studies across the globe were higher consumption of whole-grain foods, legumes, fruits, vegetables, greens, dairy, nuts, seeds, fish, poultry and egg; and lower consumption of refined grains, red & processed meat, fried food such as fries & fast food such as pizza and burgers, sweets, desserts & SSB (Green, 2016). Despite the differences in geographic locations and the specific diet pattern constituents, healthy diet patterns were associated with a lower GDM risk in eleven studies (Zhang et al., 2006a; Tobias et al., 2012; Karamanos et al., 2014; Schoenaker et

al., 2015; He et al., 2015; Tryggvadottir et al., 2016; De-Seymour et al., 2016; Izadi et al., 2016; Chen et al., 2019; Asadi et al., 2019 & Zamani et al., 2019) (details in table 1.5, pages 28 - 34). A recent systematic review indicated that eight out of eleven studies, mostly in high-income countries and in Caucasian women, show that the prudent diet pattern is associated with a lower GDM risk (Raghavan et al, 2019).

7.13.5. Strengths and limitations

BANGLES is the first study in India to explore diet patterns and GDM risk. Trained nutritionists collected dietary data using a validated FFQ directly, face to face, minimised potential errors in exposure measurement. Interviewer-administered FFQs are better in predicting actual intakes (Brassard et al., 2018). Using frequency of intake over quantified amounts makes the findings more generalisable to settings elsewhere in the world. Despite the absence of data from Vanivilas hospital (lowest socio-economic group) the study captured considerable dietary diversity among women, making it unlikely that lack of variability was an issue. Finally, confounders and mediators were measured and adjusted for in the statistical analysis. The effect of the late pregnancy dietary changes on the exposure of peri-conceptional diet, if any, could not be ascertained in this thesis. Additionally, gestational weight gain could not be measured in the study and how this could have affected the study findings cannot be established.

7.13.6. Conclusion and future directions

India has varied diets that are related to social identity, religion, culture (Vecchio et al., 2014) agriculture and availability (Subramanyam et al., 2010). The idea of an average diet pattern may always be of less importance from a public health nutrition standpoint in a country as huge as India (Green et al., 2016) where food and culture differ every 100 kilometres. Therefore, there cannot be a one-size-fits-all healthy diet pattern for public health recommendations. Nonetheless, increasing diet diversity through including fruit and vegetables, wholegrains, pulses, nuts and seeds and lower intake of processed meat, refined grains, sugar, salt and saturated fat is related to better health (WHO, 2004; Conklin et al., 2016; Foote et al., 2004).

Using a data-driven PCA method, BANGLES showed that PCA is able to capture variability between people's diets in India, and identified five peri-conceptual diet patterns among women from rural and urban Bangalore. All of these patterns had both 'healthy' and 'unhealthy' characteristics, except the third pattern. None of them were strongly related to GDM risk, and none showed significant associations with GDM after adjusting for BMI and using strict criteria to control for multiple testing. BMI may be a mediator of diet's association with GDM. In future work, I would like to delve further into my data, to a) construct a healthy food index and b) refine the quantification of food intakes using portion size data in addition to frequency of intake, in order to further study, the relationship between diet and GDM in the Indian context. It is important that others study this issue in a variety of Indian populations, in order to get a full picture, in order to (Green et al., 2016) enable researchers and policymakers to make the right recommendations to Indian women planning pregnancy.

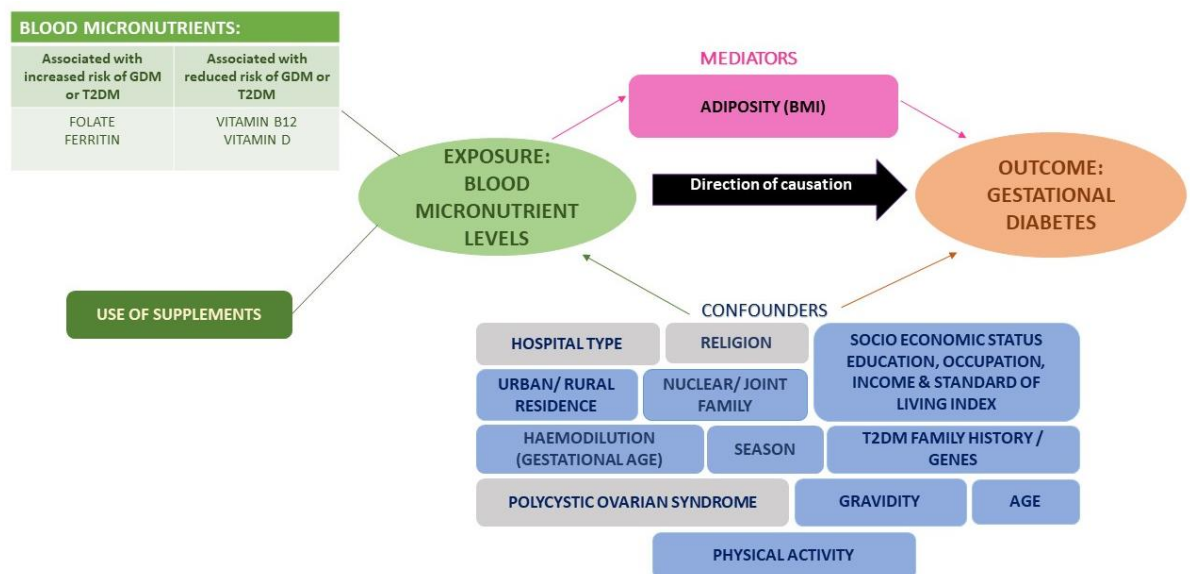
Chapter 8

Association between early pregnancy blood micronutrient levels and development of GDM

8.1. Background and aims of this chapter

Higher blood folate and ferritin have been associated with higher risk, and higher blood B12 and vitamin D with a lower risk of GDM (Silva-Zolezzi et al., 2017). However, more studies are needed in different populations to confirm these findings (Silva-Zolezzi et al., 2017). In addition to diet, early pregnancy blood micronutrient levels of folate, vitamin B12, vitamin D and ferritin were investigated as exposures in my study (reasons for studying these nutrients described in section 1.7.2, page 45). This chapter aims to explore associations of blood micronutrient levels with population characteristics and GDM (figure 8.1). I also explored women's use of micronutrient supplements in early pregnancy in relation to GDM.

Figure 8.1: Concept diagram exploring causal associations between blood micronutrient levels and GDM drawn from the literature



8.2. Description of the exposure ‘blood micronutrient levels’ in early pregnancy

For the following analysis, I have used cut-off criteria to define deficiency and sufficiency for folate, B12, vitamin D and iron from a laboratory in India that uses these, as there are no universally accepted reference values. Hence, I verified these values with a number of well-known published sources, and found them to be similar. These sources included the World Health Organisation’s report on vitamin and mineral requirements for humans, and the Institute of Medicine (IOM) guidelines (WHO, 2005 and IOM, 2011).

Table 8.1, page 222 presents blood micronutrient levels in early pregnancy. Over half of the women (53%) in the study were not folate deficient, 46% had ‘high’ folate levels and only 1 percent (n=3) were deficient. In further analyses, these 3 were regrouped as ‘normal’ because regression analysis with sub-groups comprising small numbers of participants may not meet assumptions of parametric statistical tests. The majority of women (88%) had normal plasma vitamin B12 levels, with 10% deficient and 2% severely deficient. Half the women were vitamin D deficient. Close to half (48%) of the women had borderline serum ferritin levels, 32.9% had low levels and the remaining 19% had normal levels. None had high ferritin levels.

Table 8.1: Blood micronutrient levels in early pregnancy using clinical cut-offs among GDM women and controls (n=304)

Blood Micronutrient	Clinical cut-off values (units)	N (%)
Plasma folate	Deficient: <3 ng*/ml	3 (1.0)
	Not deficient : ≥3-20 ng*/ml	161 (53.0)
	High: >20 ng*/ml	140 (46.1)
Plasma vitamin B12	Severe deficiency: ≤136 pg*/ml	6 (2.0)
	Deficiency: ≤203 pg*/ml	32 (10.5)
	Normal: >203 pg*/ml	266 (87.5)
Plasma vitamin D	Deficient: <28 nmol*/l	154 (50.7)
	Normal: >28 nmol*/l	150 (49.3)
Serum ferritin	Low: ≤15 ng*/ ml	100 (32.9)
	Borderline: 16 – 40 ng*/ml	147 (48.3)
	Normal: 41 – 400 ng*/ml	57 (18.8)
	High: >400 ng*/ ml	0 (0)

*ng/ml = nanograms-per-millilitres; pg/ml = picograms-per-millilitres; nmol/l = nanomoles-per-litre.

8.3. Univariate associations between early pregnancy blood micronutrient levels and population characteristics (potential confounders and the mediator)

Rural women and women from joint families had higher plasma vitamin D levels compared to urban women and women from nuclear families (odds ratio for deficiency: 0.42, 95% CI: 0.25, 0.72 and 0.60, 95% CI: 0.38, 0.95 respectively). Area of residence and family type were not associated with folate, vitamin B12 or ferritin levels (table 8.2 & table 8.3, page 224).

A higher age was associated with higher blood levels of folate, B12 and ferritin while the opposite was true for vitamin D (table 8.4, page 225). Higher BMI was associated with lower vitamin D levels. BMI was not associated with blood levels of folate, vitamin B12 and ferritin (table 8.5, page 226).

Women who had a family history of T2DM had higher serum ferritin levels than those with no history. History of T2DM was not associated with differences in blood levels of folate, vitamin D and vitamin B12. Season of blood collection (less sunlight seasons including winter & monsoon vs. more sunlight including summer & spring) was not associated with vitamin D levels or any of the blood micronutrient levels. Gestational age was studied, to look for evidence of haemodilution, which increases with gestation. Higher gestational age was associated with higher vitamin D levels ($p=0.01$), but folate, B12 and ferritin were not associated with gestational age. Physical activity was not associated with any of the blood micronutrient levels (data not shown).

Table 8.2: Univariate regression analysis of participant's area of residence as a predictor of the blood micronutrient levels in early pregnancy (n=301*)

Outcome: Blood micronutrient levels	Median (IQR) of blood micronutrient levels	N (%) in each outcome category	Predictor: Area of residence Urban = 0, Rural = 1		
			OR ¹ / β ²	95% CI	p
Plasma folate ¹ (ng/ml): categorical variable, 0 = Normal; 1 = High					
Urban	19.1 (11.9, 20.0)	0 = 120 (73.6) 1 = 102 (73.9)	1	-	-
Rural	19.6 (13.1, 20.0)	0 = 43 (26.4) 1 = 36 (26.1)	0.98 ¹	0.58, 1.57	0.81
Plasma vitamin D ¹ (nmol/L): categorical variable, 0 = Normal; 1=Deficiency					
Urban	24.6 (16.2, 37.2)	0 = 97 (65.5) 1= 125 (81.7)	1	-	-
Rural	33.1 (24.4, 43,1)	0 = 51 (34.5) 1 = 28 (18.3)	0.42 ¹	0.25, 0.72	0.002
Plasma vitamin B12 ² (nmol/L): continuous variable, log transformed and z-standardised; units = SD					
Urban	349.0 (250.7,591.7)	222 (73.7)	-0.14 ²	-0.40, 0.11	0.26
Rural	351.0 (222.0, 546.0)	79 (26.3)			
Serum Ferritin ² (ng/ml): continuous variable, log transformed and z-standardised; units = SD					
Urban	24.0 (14.3, 38.5)	222 (73.7)	-0.19 ²	-0.45, 0.06	0.13
Rural	22.1 (11.4, 28.9)	79 (26.3)			

*missing data for 3 women.

¹ Micronutrient variables were used as categorical binary variables in logistic regression.² Micronutrient variables were used as continuous variables, transformed and z-standardised and used in linear regression, with unstandardized linear regression coefficients.**Table 8.3: Univariate regression analysis of participant's family type as a predictor of the blood micronutrient levels in early pregnancy (n=304)**

Outcome: Blood micronutrient levels	Median (IQR) levels of blood micronutrient levels	N (%) in each outcome category	Predictor: Family type		
			Nuclear=0, Joint = 1		
			OR ¹ / β ²	95% CI	p
Plasma folate ¹ (ng/ml): categorical variable, 0 = Normal; 1 = High					
Nuclear	19.5 (12.3, 20.0)	0 = 94 (57.3) 1 = 81 (57.9)	1	-	-
Joint	18.8 (12.1, 20.0)	0 = 70 (42.7) 1 = 59 (42.1)	0.92 ¹	0.62, 1.54	0.92
Plasma vitamin D ¹ (nmol/L): categorical variable, 0 = Normal; 1 = Deficiency					
Nuclear	24.8 (17.2, 38.3)	0 = 77 (51.3) 1 = 98 (63.6)	1	-	-
Joint	31.1 (17.1, 40.6)	0 = 73 (48.7) 1 = 56 (36.4)	0.60 ¹	0.38, 0.95	0.03
Plasma vitamin B12 ² (nmol/L): continuous variable, log transformed and z-standardised: units = SD					

Outcome: Blood micronutrient levels	Median (IQR) levels of blood micronutrient levels	N (%) in each outcome category	Predictor: Family type Nuclear=0, Joint = 1		
			OR ¹ / β^2	95% CI	p
Nuclear	351.0 (258.0, 565.0)	175 (57.6)	-0.03 ²	-0.26, 0.19	0.75
Joint	349.0 (235.0, 572.5)	129 (42.4)			
Serum Ferritin ² (ng/ml): continuous variable, log transformed and z-standardised; units = SD					
Nuclear	23.2 (12.9, 36.0)	175 (57.6)	0.03 ²	-0.19, 0.26	0.77
Joint	22.0 (13.4, 34.9)	129 (42.4)			

¹ Micronutrient variables were used as categorical binary variables in logistic regression.
² Micronutrient variables were used as continuous variables, transformed and z-std. and used in linear regression, with unstandardized linear regression co-efficients.

Table 8.4: Univariate regression analysis of participant's age as a predictor of blood micronutrient levels in early pregnancy (n=304)

Blood micronutrient levels	Median (IQR) levels of blood micronutrient levels	N (%) in each outcome category	Predictor: Age (years)		
			OR ¹ / β^2	95% CI	p
Plasma folate ¹ : categorical variable, 0 = Normal, 1 = High					
<22 years	15.3 (8.7, 20.0)	0 = 22 (13.4) 1 = 12 (8.6)	1.04 ¹	0.98, 1.09	0.04
22 to 26 years	19.4 (12.9, 20.0)	0 = 45 (27.4) 1 = 39 (27.9)			
26 to 30 years	19.4 (12.7, 20.0)	0 = 52 (31.8) 1 = 42 (30.0)			
>30 years	20.0 (11.8, 20.0)	0 = 45 (27.4) 1 = 47 (33.5)			
Plasma vitamin D ¹ : categorical variable, 0 = Normal, 1 = Deficiency					
<22 years	33.9 (22.3, 43.8)	0 = 25 (16.7) 1 = 9 (5.8)	1.06 ¹	1.00, 1.11	0.02
22 to 26 years	25.9 (17.6, 40.9)	0 = 39 (26.0) 1 = 45 (29.2)			
26 to 30 years	26.6 (17.0, 36.4)	0 = 45 (30.0) 1 = 49 (31.8)			
>30 years	24.8 (16.6, 41.1)	0 = 41 (27.3) 1 = 51 (33.2)			
Plasma vitamin B12 ² : continuous variable, log transformed and z-standardised (SD)					
Age as a continuous variable		304 (100.0)	0.02 ²	0.00, 0.05	0.05
Age as categories:		B12 categories (0=Normal; 1 = Deficiency)			
<22 years	320.5 (242.2, 452.5)	0 = 31 (11.4) 1 = 3 (9.4)			
22 to 26 years	326.5 (234.7, 492.7)	0 = 76 (27.9) 1 = 8 (25.0)			
26 to 30 years	380.5 (227.0, 661.7)	0 = 81 (29.8) 1 = 13 (40.6)			
>30 years	377.5 (276.7, 645.2)	0 = 84 (30.9) 1 = 8 (25.0)			

Blood micronutrient levels	Median (IQR) levels of blood micronutrient levels	N (%) in each outcome category	Predictor: Age (years)		
			OR ¹ / β ²	95% CI	p
Serum Ferritin ² : categorical variable, 0 = Normal; 1 = Low & 2 = Borderline					
Age as a continuous variable		304 (100.0)	0.03 ²	0.00, 0.05	0.01
Age as categories:					
<22 years	14.0 (8.0, 24.8)	0 = 2 (3.5) 1 = 19 (19.0) 2 = 13 (8.8)			
22 to 26 years	25.4 (13.8, 36.0)	0 = 13 (22.9) 1 = 26 (26.0) 2 = 45 (30.6)			
26 to 30 years	24.0 (12.9, 38.1)	0 = 21 (36.8) 1 = 31 (31.0) 2 = 42 (28.6)			
>30 years	24.0 (15.3, 36.7)	0 = 21 (36.8) 1 = 24 (24.0) 2 = 47 (32.0)			
¹ Micronutrient variables were used as categorical binary variables in logistic regression models.					
² Micronutrient variables were used as continuous variables, transformed and z-std. and used in linear regression. with unstandardized linear regression co-efficients.					

Table 8.5: Univariate regression analysis of participant's BMI as a predictor of the blood micronutrient levels in early pregnancy (n=297*)

Blood micronutrient levels	Median (IQR) levels of blood micronutrient levels	N (%) in each outcome category	Predictor: BMI (Kg/m ²)		
			OR ¹ / β ²	95% CI	p
Plasma folate ¹ : categorical variable, 0 = Normal and 1 = High.					
BMI as a continuous variable	-	297 (100.0)	1.04 ¹	-0.01, 0.09	0.11
Underweight	15.2 (10.9, 20.0)	0 = 7 (4.4) 1 = 6 (4.4)			
Normal	18.3 (11.5, 20.0)	0 = 76 (47.5) 1 = 61 (44.5)			
Overweight	19.5 (12.9, 20.0)	0 = 59 (36.9) 1 = 49 (35.8)			
Obese	20.0 (12.6, 20.0)	0 = 18 (11.3) 1 = 21 (15.3)			
Plasma vitamin D ¹ : categorical variable, 0 = Normal and 1 = Deficiency.					
BMI as a continuous variable	-	297 (100.0)	1.08 ¹	1.03, 1.14	0.002
Underweight	32.6 (17.8, 40.6)	0 = 7 (4.8) 1 = 6 (4.0)			
Normal	30.0 (19.3, 42.6)	0 = 79 (54.1) 1 = 58 (38.4)			
Overweight	23.2 (16.5, 35.7)	0 = 45 (30.8) 1 = 63 (41.7)			
Obese	21.1 (16.2, 35.2)	0 = 15 (10.3) 1 = 24 (15.9)			
Plasma vitamin B12 ² : continuous variable, log transformed and z-standardised (SD)					

Blood micronutrient levels	Median (IQR) levels of blood micronutrient levels	N (%) in each outcome category	Predictor: BMI (Kg/m ²)		
			OR ¹ / β ²	95% CI	p
BMI as a continuous variable	-	297 (100.0)	-0.01 ²	-0.03, 0.01	0.58
BMI as categories:					
Underweight	478.0 (273.5, 609.0)	13 (4.4)			
Normal	356.0 (245.5, 552.5)	137 (46.2)			
Overweight	342.0 (261.0, 540.2)	108 (36.4)			
Obese	342.0 (210.0, 634.0)	39 (13.2)			
Serum Ferritin ² : categorical variable, 0 =Normal; 1 = Low & 2 = Borderline					
BMI as a continuous variable	-	297 (100.0)	0.01 ²	-0.01, 0.03	0.48
BMI as categories:					
Underweight	27.5 (11.3, 33.3)	13 (4.4)			
Normal	21.7 (11.3, 34.3)	137 (46.1)			
Overweight	22.7 (14.4, 36.8)	108 (36.4)			
Obese	26.5 (13.4, 34.3)	39 (13.1)			

*N=297, BMI missing for 7 women.

¹ Micronutrient variables were used as categorical binary variables in logistic regression models.

² Micronutrient variables were used as continuous variables, transformed and z-std. and used in linear regression, with unstandardized linear regression co-efficients.

8.4. Univariate associations between early pregnancy blood micronutrient levels and other population characteristics (non-confounders)

I used regression models to study associations between other population characteristics and early pregnancy blood micronutrient levels (data not shown), and only significant associations are reported here). Women from Cloudnine hospital had higher plasma vitamin B12 levels ($p < 0.001$) and serum ferritin levels ($p = 0.001$) than women from Baptist hospital (median B12 levels: 330 & 542 nmol/L in Baptist & Cloudnine respectively, $p < 0.001$). Muslim women had lower plasma vitamin D levels compared to Hindu women ($p = 0.05$). A higher SLI score was associated with higher serum ferritin levels ($p = 0.05$). A higher family income was associated with higher plasma vitamin B12 and serum ferritin levels ($p = 0.01$ and $p = 0.01$ for B12 and ferritin respectively). The lowest level of education (high school or less) was used as the reference group, compared with higher levels of education (intermediate

and pre-university, graduate and post-graduate). A higher level of the participant's education ($p=0.05$ for postgraduates) was associated with higher serum ferritin levels.

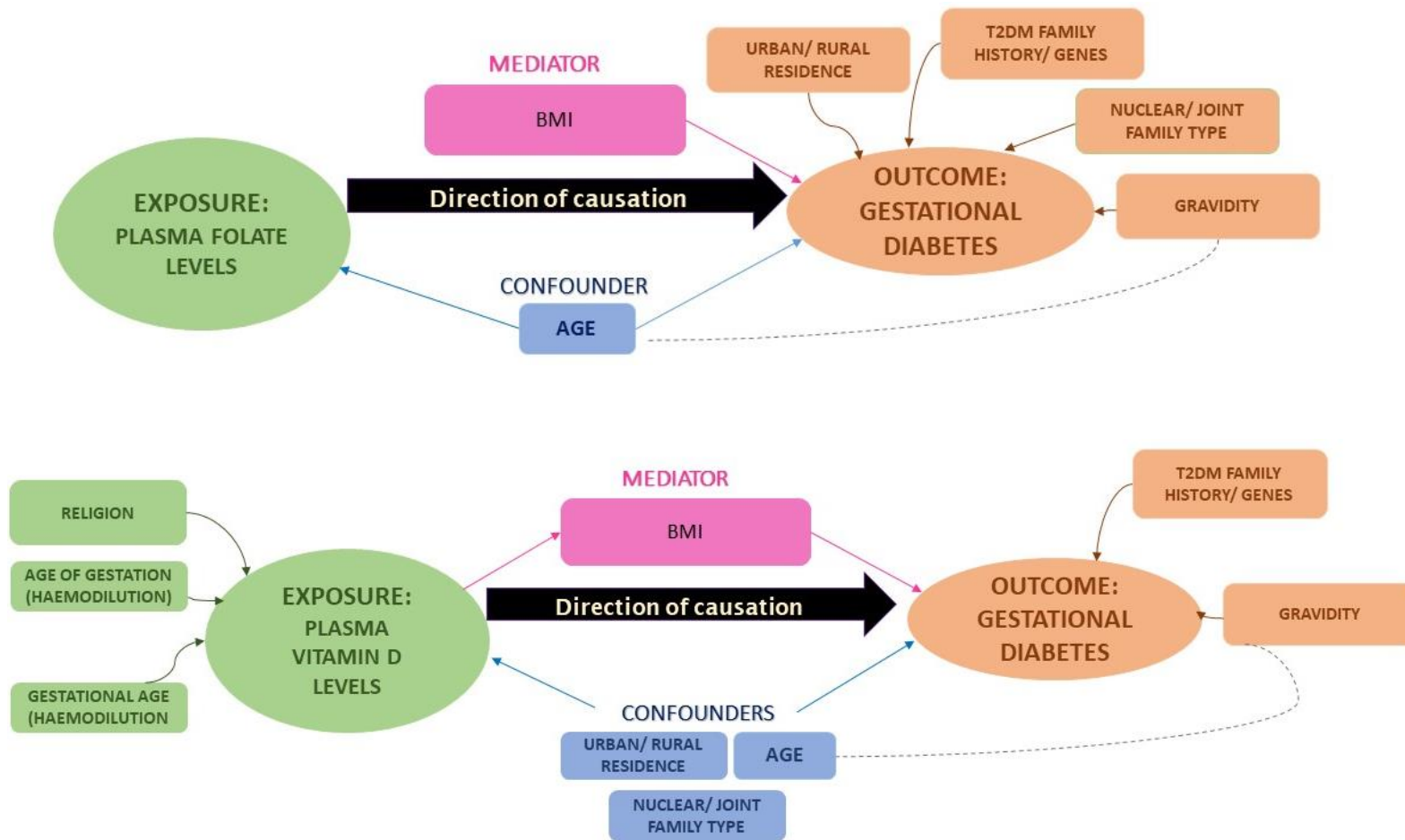
8.5. Reviewing the concept diagram

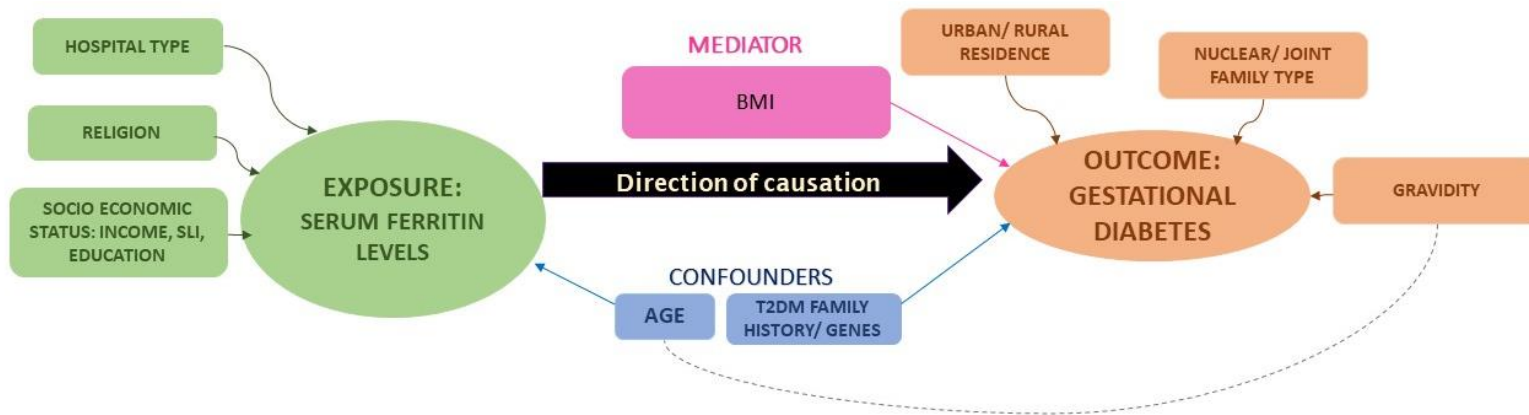
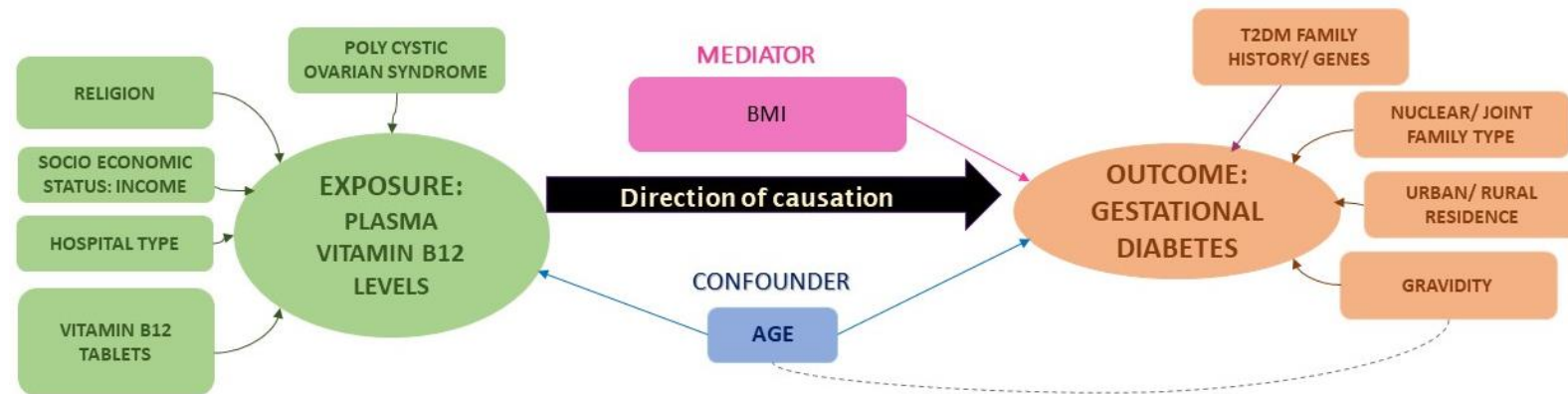
Concept diagrams for each blood micronutrient drawn from the analysis of univariate associations of population characteristics as predictors of blood micronutrient levels have been summarised in figure 8.2, pages 229 & 230. Folate was associated with age. Vitamin D was associated with area of residence, family type, age, BMI, haemodilution and religion. Vitamin B12 was associated with age, hospital type, income and PCOS. Ferritin was associated with age, family history of T2DM, hospital type, SLI, income and education level. As shown earlier, age, urban or rural residence, nuclear or joint family type and family history of T2DM were associated with GDM (5.5, page 162 - 164). Based on these findings, multivariate regression analyses were carried out with blood micronutrient levels as predictors of GDM, in separate models for each micronutrient. For folate, age was treated as a confounder. For vitamin B12, age, area of residence and family type were treated as confounders, for vitamin D, age, area of residence and family type were treated as confounders and for ferritin, age and family history of T2DM were treated as confounders. Additionally, I ran separate models adjusting for BMI, to test whether it could be a mediator of any associations between blood micronutrient levels and GDM.

8.6. Univariate associations between blood micronutrient levels and GDM

Table 8.6, page 232 shows the micronutrient status of women who did and did not develop GDM. Plasma folate, vitamin B12 and vitamin D were not associated with GDM (table 8.7, page 233). Serum ferritin as a continuous variable was not associated with GDM (table 8.7, page 233). However, serum ferritin as a categorical variable with clinical cut-offs was associated with GDM. Women with low or borderline serum ferritin levels (≤ 15 and 16-40 ng/ml) had a lower risk of GDM compared to women with normal serum ferritin levels of 41-400 ng/ml

Figure 8.2: Concept diagrams exploring causal associations between blood micronutrient levels and GDM drawn from chapter findings





(OR: 0.47, 95% CI: 0.24, 0.93, $p=0.03$, OR: 0.50, 95% CI: 0.26, 0.94, $p=0.03$ respectively) (table 8.7).

8.7. Multivariate associations between the early pregnancy blood micronutrient levels, confounders, mediator and GDM

Table 8.7, page 233 shows that plasma folate, vitamin B12, vitamin D and ferritin (continuous variable) remained unassociated with GDM after adjusting for appropriate confounders. Similarly, the association of low and borderline serum ferritin levels with a lower GDM risk compared to women with normal serum ferritin levels remained statistically significant ($p=0.01$ and 0.03), after adjusting for confounders. In order to check that this was not because of residual confounding, I also adjusted for hospital type, urban/rural residence, education, income and SLI; the findings were unchanged ($p=0.01$ and $p=0.03$ respectively for low and borderline levels). They also remained significant when BMI was added into the model, indicating that BMI was not a mediator of the associations observed. The regression model using the *a priori* confounders (model 3) also showed that women with lower ferritin levels had lower GDM risk (aOR: 0.39, 95% CI: 0.17, 0.90, $p=0.02$), however, the borderline ferritin level-GDM association was not seen. Folate, B12, and vitamin D levels were not associated with GDM.

8.8. Associations between the early pregnancy use of supplements and GDM

Use of micronutrient tablets is usually closely linked to blood levels (shown in table 9.8, page 256). Hence I checked the association of their use with GDM. Women in the study used folate, iron, calcium-vitamin D, B12 and energy-protein supplements. Women taking iron supplements in early pregnancy were almost always taking calcium+vitamin D tablets too, to the extent that I could not separate the effects of these supplements individually and had to consider them as one exposure. I observed that the use of folate, B12 and energy protein

supplements was not associated with GDM, either in the subsample of 304 or the whole sample of 785.

In univariate models (n=785), use of iron and calcium-vitamin D supplements was associated with higher GDM risk (table 8.8). These findings persisted in multivariate models after adjusting for all *a priori* determined population characteristics as potential confounders including age, family history of T2DM, gravidity, PCOS status, physical activity, BMI, education & occupation levels, family type, income, SLI score, area of residence and use of other supplements. Associations remained statistically significant after adjusting for multiple testing, using the Bonferroni correction, which mandates a significance threshold of $p < 0.01$ ($0.05/4$).

Table 8.6: Early pregnancy micronutrient status of women who did and did not develop GDM

	GDM N=151	Non-GDM N=151
Continuous micronutrient variables	Median (IQR)	Median (IQR)
Folate (ng/ml)	19.2 (12.9, 20.0)	19.5 (12.0, 20.0)
Vitamin B12 (pg/ml)	374.0 (275.0, 548.0)	327.0 (226.0, 623.0)
Vitamin D (nmol/l)	26.5 (17.1, 37.9)	29.1 (17.2, 41.4)
Ferritin (ng/ml)	25.9 (14.3, 38.0)	20.9 (10.6, 32.2)
Categorical micronutrient variables	N (%)	N (%)
Folate		
Deficient* (<3 ng/ml)	3 (2.0)	0 (0.0)
Normal (3-20 ng/ml)	82 (54.3)	78 (51.7)
High (>20 ng/ml)	66 (43.7)	73 (48.3)
All	151 (100.0)	151 (100.0)
Vitamin B12		
Severe deficiency (<136 pg/ml)	2 (1.3)	3 (2.0)
Deficiency (136-203 pg/ml)	12 (7.9)	20 (13.2)
Normal (>203 pg/ml)	137 (90.7)	128 (84.8)
All	151 (100.0)	151 (100.0)
Vitamin D		
Deficient (<28 nmol/l)	81 (53.6)	70 (46.4)
Normal ($\geq$ 28 nmol/l)	73 (48.3)	78 (51.7)
All	151 (100.0)	151 (100.0)
Ferritin		
Low ($\leq$ 15 ng/ml)	46 (30.5)	54 (35.8)
Borderline (16-40 ng/ml)	69 (45.7)	77 (51.0)
Normal (41-400 ng/m)	36 (23.8)	20 (13.2)
High (>400 ng/ml)	0 (0)	0 (0)
All	151 (100.0)	151 (100.0)

Table 8.7: Univariate and multivariate regression analysis of the early pregnancy blood micronutrient levels as predictors of GDM (n=302)

Predictors	Outcome=GDM (No=0, Yes=1)								
	Univariate model			Multivariate model 1 ³			Multivariate model 2 ⁴		
For the categorical predictors, the reference group was the normal group in every case	OR	95% CI	p	aOR	95% CI	p	aOR	95% CI	p
Folate ² , categorical ¹ variable, 0=normal, 1=high	0.83	0.52, 1.30	0.41	0.83	0.52, 1.32	0.42	0.82	0.48, 1.40	0.47
Vitamin B12, continuous variable, log transformed and z-standardized	1.08	0.86, 1.35	0.53	1.08	0.86, 1.36	0.51	1.09	0.84, 1.42	0.48
Vitamin B12, categorical ¹ variable, 0=normal, 1=deficient or severely deficient	0.56	0.28, 1.15	0.11	0.56	0.28, 1.15	0.11	0.59	0.24, 1.44	0.25
Vitamin D, categorical ¹ variable, 0=normal, 1=deficient	1.23	0.78, 1.94	0.35	1.22	0.76, 1.95	0.40	0.94	0.54, 1.62	0.83
Ferritin, continuous variable, log transformed and z-standardised	1.10	0.87, 1.38	0.41	1.08	0.85, 1.36	0.55	1.19	0.90, 1.58	0.20
Ferritin, categorical ¹ variable, 0=normal, 1=borderline (upper row), 2=low (lower row)	0.47 0.50	0.24, 0.93 0.26, 0.94	0.03 0.03	0.44 0.38	0.21, 0.92 0.17, 0.83	0.03 0.01	0.49 0.39	0.22, 1.08 0.17, 0.90	0.07 0.02

¹For categorical predictors, the categories are as in Table 8.6.

²For folate, women with deficiency (n=3) were excluded due to the small number. For the continuous predictors, the OR is per SD change in the predictor.

³Multivariate model 1: adjusted for data-driven confounders: Folate and vitamin B12 adjusted for age; Vitamin D adjusted for age, area of residence and family type; Ferritin adjusted for age and family history of T2DM.

⁴Multivariate model 2: adjusted for a priori confounders: age, gravidity, PCOS status (no/yes), area of residence (urban/rural), family history of T2DM (no/yes), physical activity (weekly light walking) and SES measures (SLI score, income, education & occupation levels).

Table 8.8: Univariate and multivariate regression analysis of the use of nutrient supplements as predictors of GDM (n=714*)

Predictor: Nutrient supplements	Use: Yes/ N	N (%) in each outcome category		Outcome: GDM (0 = no , 1 = yes)		
		Non-GDM	GDM	OR	95% CI	p
Use of Iron and Calcium/vitamin D tablets*						
Univariate	No	414 (80.5)	100 (19.5)	1	-	-
	Yes	143 (71.5)	57 (28.5)	1.65	1.13, 2.40	0.009
Multivariate ^a	No	414 (80.5)	100 (19.5)	1	-	-
	Yes	143 (71.5)	57 (28.5)	1.91	1.21, 3.01	0.005
Use of B12 tablets**						
Univariate	No	507 (78.0)	143 (22.0)	1	-	-
	Yes	50 (78.1)	14 (21.9)	0.99	0.53, 1.84	0.98
Multivariate ^b	No	507 (78.0)	143 (22.0)	1	-	-
	Yes	50 (78.1)	14 (21.9)	0.77	0.35, 1.69	0.52
Use of folate tablets**						
Univariate	No	79 (75.2)	26 (24.8)	1	-	-
	Yes	475 (78.4)	131 (21.6)	0.83	0.51, 1.35	0.47
Multivariate ^c	No	79 (75.2)	26 (24.8)	1	-	-
	Yes	475 (78.4)	131 (21.6)	0.75	0.41, 1.38	0.38
Use of energy and protein supplements**						
Univariate	No	369 (76.4)	114 (23.6)	1	-	-
	Yes	188 (81.4)	43 (18.6)	0.74	0.50, 1.09	0.13
Multivariate ^d	No	369 (76.4)	114 (23.6)	1	-	-
	Yes	188 (81.4)	43 (18.6)	0.82	0.51, 1.33	0.42

*N missing for PCOS = 1; monthly family income = 148; area of residence = 13 & BMI = 23.

**Dosage per tablet: Iron 50 - 60 mg; Vitamin D + Calcium 200 IU + 1000 mg; B12 500 – 1500 µg in some iron supplement brands; folate 5 mg & Energy protein tablets 250 k calories + other nutrients, with differences in each brand.

***p: significance correction for multivariate models using bonferroni's correction at 0.05 level is 0.01.

^{a, b, c & d} All models adjusted for *a priori* confounders including woman's age, family history of T2DM (no/yes), gravidity, PCOS status (no/yes), education & occupation levels, physical activity (weekly light walking), BMI, SES indicators (monthly family income, SLI score, education & occupation levels), family type (nuclear/joint) and area of residence (urban/ rural).

Additionally, models were adjusted for use of other nutrient supplements as follows:

^a B12, folate & energy protein (Iron and calcium-vitamin D treated as a single exposure since women taking iron supplements also took calcium-vitamin D supplements)

^b iron, calcium – vitamin D, folate & energy protein

^c iron, calcium – vitamin D, B12 & energy protein and

^d iron, calcium – vitamin D, B12 & folate.

8.9. Discussion

8.9.1. Summary of chapter findings

Plasma levels of folate, vitamin B12 and vitamin D in early pregnancy were not associated with GDM risk. Serum ferritin levels used as a continuous variable were not associated with GDM risk. These findings remained consistent in univariate and multivariate models for each micronutrient, after

adjusting for their respective confounders. However, women with low serum ferritin levels in early pregnancy had a lower GDM risk, than women with normal ferritin levels. Women using iron and calcium-vitamin D tablets in early pregnancy had a 2.1 times higher risk of GDM, compared to women who did not use these supplements. This association remained significant after adjusting for confounders and after Bonferroni's correction. Use of folate and B12 supplements in early pregnancy were not associated with GDM risk.

8.9.2. Comparing the findings with the existing literature

Ferritin: Studies have found associations between higher blood ferritin and higher GDM (Chen et al., 2006; Bowers et al 2016 and Sedigheh et al., 2017) and T2DM risk (Arija et al., 2014). A meta-analysis (N=44,110) that investigated the association between iron biomarkers and GDM, found a positive association between ferritin and GDM risk (aOR: 1.6, 95% CI: 1.2, 2.1). This meta-analysis included sixteen studies to date (from Iran, Turkey, Lebanon, China, Spain, USA, Australia, Greece and Denmark). The authors suggested interpreting the results with caution due to the heterogeneity of studies used in the analysis (Kataria et al., 2018). Another systematic review and meta-analysis of 11 observational studies assessing iron levels, found that a high ferritin was associated with an increased GDM risk (OR: 2.09, 95% CI: 1.5, 2.9) (Fernández-Cao et al., 2016). There are no Indian studies investigating the ferritin-GDM association to compare with my findings.

There are knowledge gaps about optimal ferritin levels among pregnant women, and most studies use the clinical reference values for healthy adult women. However, in pregnancy there is haemodilution and higher foetal demands for iron (Kataria et al., 2018 & OpeN Global., 2019). Iron plays a role in many cellular functions, acting as a cofactor for many enzymes and transporting oxygen. Iron is required for foetal development and low iron stores increase the risk of neonatal morbidity and pre-term birth (Milman et al., 2008). However, high iron stores have been associated with adverse pregnancy outcomes such as low birth weight, stillbirth, pre-eclampsia and GDM, and this may be because high iron levels make the blood more viscous, reducing placental perfusion (Iqbal & Ekmekcioglu, 2017). Iron is associated with oxidative stress as it acts as a catalyst to generate hydroxyl free

radicals (Zein et al., 2015). There are 2 sides to the effects of these free radicals; while low levels can improve insulin sensitivity, high levels have been associated with hyperglycaemia (Rajpathak et al., 2009) and subsequently increased GDM (Zein et al., 2015). Excessive iron levels may damage pancreatic beta cells since they are more susceptible to iron accrual than other cells (Rahier et al., 1987). Also, beta cells have reduced antioxidant capacity, making them more prone to damage from oxidative stress, leading to apoptosis and consequently diminished insulin secretion (Lenzen et al., 2008). Future research should study iron requirements and normal ferritin levels during pregnancy, with a background of the risk excess iron poses.

Vitamin D: Vitamin D was not associated with GDM in my study. In contrast, a systematic review of 87 observational studies (N = 55,859) and 25 RCTs (N=2,445) found that lower vitamin D levels during pregnancy were associated with a higher GDM risk (OR: 1.85, 95% CI: 1.47, 2.32) (Zhang et al., 2018). Two observational studies in India have reported similar findings (Farrant et al., 2009 & Dwarkanath et al., 2019) (described in 1.6.2, page 43).

Folate & B12: My study did not find any associations between blood folate and B12 levels in early pregnancy and GDM risk, unlike other studies. Two studies to date have shown positive association between blood folate levels and GDM risk in Singapore and China (Lai et al., 2018 & Xie et al., 2019) (details, pages 41 - 42). One study did not find an association between maternal blood folate and GDM however, reported higher cord blood folate levels among women with GDM than controls. The authors suggested that the possible reasons for this could be that: a) folate levels are higher in cord blood than maternal blood, suggesting differences in feto-placental active transport and metabolism of folate. b) A higher folic acid is required to maintain intracellular folic acid homeostasis in GDM affected cells (Barzilay et al., 2018). My study did not collect cord blood to explore this finding.

Three studies have shown an inverse association between blood B12 levels and GDM risk in Mysore, UK and Singapore. (Krishnaveni et al., 2009 ; Sukumar et al., 2016 & Lai et al., 2018) (study details described in Chapter 1 in pages 41 - 42).

8.9.3. Possible reasons for not finding blood micronutrient level – GDM associations

Synthetic micronutrients in the form of tablets, beverage supplements and fortified foods (breakfast cereals and flavoured drinks) contain high amounts of folate, B12 and iron compared to natural dietary sources. For example, the richest natural dietary source of B12, fish and meat, provide between *4 and 20 µg of natural vitamin B12/ 100g* whereas, B12 tablets can provide *500 - 1500 µg of synthetic B12*. Furthermore, folate tablets distributed universally to pregnant women in India contain 5000 µg when the recommendation is 600 µg (WHO, 2005), and the upper tolerable limit of 5000 µg is recommended for women with a history of neural tube defects (WHO, 2005). As a result, most women in BANGLES were folate and B12 sufficient, and for B12, there were few in the deficiency group to be compared against the nutrient sufficient group. An important message emerges from these findings for future studies that, it is indeed challenging to do such studies measuring blood micronutrient levels and exploring associations with any health outcome. Women take multiple brands of synthetic micronutrients with varying nutrient profiles, through medical and self-prescriptions (after seeing online advertisements), and these are difficult to record accurately. Also compliance with iron tablets, which are associated with side-effects such as acidity or constipation, may not be reported accurately by women.

8.9.4. Effects of excessive use of synthetic micronutrients

My study showed that women taking iron and calcium-vitamin D supplements when they were recruited in early pregnancy had a higher GDM risk. It is common in India for obstetricians to start iron and calcium-vitamin D supplements at the same time during early pregnancy (1st or 2nd trimester) and all women taking one of these supplements were also taking the other. It is therefore not possible to determine from my data whether iron or calcium-vitamin D, or both, is associated with the increased risk. Previous literature, however, from countries with different prescribing habits, provides some support for iron supplements, but not calcium-vitamin D, being associated with GDM. A study found that Italian women using iron supplements during mid-pregnancy had a double to triple fold increased risk

of GDM after adjusting for age, diabetes in first-degree relatives, BMI, education, smoking, parity, duration of iron supplementation, and current employment (Bo et al., 2009). This is in line with other epidemiological studies (Casanueva et al., 2003; Lachili et al., 2001; Lao et al 2001; Chen et al., 2006 and Iqbal & Ekmekcioglu et al., 2017) including a randomised controlled trial (Ziaei et al., 2007). In contrast, an RCT (n=1164) in Hong Kong that involved an intervention of 60 mg of iron versus placebo in the control group for 12 weeks did not show effect on GDM risk (Chan et al., 2009). Studies investigating sTfR and ratio of sTfR and ferritin (Alam et al., 2018) have not shown any associations with GDM (page 44). Ferritin levels were not available for all women in the study, to understand if the intake of supplements are associated with high ferritin levels as well. Other studies have found that ferritin levels were higher in women who were taking iron supplements and supplements were the main determinants of ferritin levels (Lachili et al., 2001 and Liu et al., 2003).

Pregnant women may be prone to high oxidative stress because of a greater basal oxygen intake by the mitochondria-rich placenta (Casanueva et al., 2003). Iron is readily available in the placenta and is a source of free radicals that lead to oxidative stress. Higher iron levels also stimulate oxidation of non-esterified fatty acids and inhibit insulin removal in the liver, which may result in peripheral hyperinsulinemia (Ferranini et al., 2000). Iron absorption in the body is a controlled mechanism where body iron stores are inversely related to absorption (Rajpathak et al., 2009). The mucosal cells in the small intestine are continually exposed to excess unabsorbed iron and further oxidative stress with supplements delivering as much as 60 mg of elemental iron (Casanueva et al., 2003). Oxidative stress can damage the intestinal epithelium and can increase the proportion of potentially enteropathogenic bacterial species and decrease beneficial species such as lactobacilli and bifidobacteria, which may lead to systemic inflammation (Zimmermann et al., 2010). In my study, the participants took about 50 mg of elemental iron per day that is routinely prescribed for all pregnant women in India as per WHO recommendations (WHO, 2005). This is the best available evidence currently, but future studies are needed to carefully evaluate whether India can afford a more individually tailored iron prophylaxis programme based on iron status, rather than a general prophylaxis programme, and if it is sustainable

long-term in low resource settings. Role of iron supplements in the aetiology of GDM requires further research.

In contrast, there is no supporting epidemiological or biological plausibility evidence that suggest a higher GDM risk with the use of calcium and vitamin D supplements. In fact, some emerging evidence suggests that calcium and vitamin D may prevent GDM (Asemi et al., 2014).

There may be a perception that nutrient supplements of any kind improve health and are beneficial, especially for pregnant women (observed during data collection). Therefore, supplements marketed online without labelling are used by some women (figure 8.3, page 241). Advertisements by the nutraceutical industry are misleading when they say that consuming their products are the main approach to combating anaemia, when these products are *calorie and sugar rich*. Also their recommended servings are large (2 scoops = 35 grams) to be added to milk, contain 350 kilo calories per serving (figure 8.3), They ignore the fact that pregnant women increase their food intake. Excess calories may lead to rapid weight gain and metabolic imbalances, and the effect of many types of excess micronutrients is not known.

8.9.5. Strengths and limitations

There was not a single study in India that investigated ferritin levels and GDM risk, and BANGLES may be the first. A strength of the study is that all population characteristics that may be associated with the exposure blood micronutrient levels were explored and confounders were adjusted for in the analysis. The exclusion criteria of recruiting participants up to 17 weeks' gestation reduced variability in haemodilution to an extent. Women diagnosed with GDM for whom blood data was available were age and BMI matched with controls. Measuring serum ferritin is a strength because ferritin is the main storage protein for iron in tissues and contains about two-thirds of the total body's iron. It is found in all cells and most is stored in liver, macrophages in bone marrow and spleen, hence is a source of readily available iron for haemoglobin and haem protein synthesis (Open Global, 2019). For all these reasons ferritin concentration is positively correlated to total body iron stores. This makes serum ferritin an ideal, non-

invasive marker of iron levels (WHO, 2011). It is widely used for clinical purposes to measure iron deficiency (Open Global, 2019).

Study weaknesses were that only a subset of the sample (304 out of 785) had blood micronutrient levels measured, due to limited resources. Ferritin as a marker of iron status has limitations in that it is elevated in acute and chronic inflammation. Other markers of inflammation such as C-reactive protein would have been useful to interpret blood ferritin levels. An alternative test to serum ferritin is the sTfR, that is not affected by inflammation (Akinsooto et al., 2001), but was nearly five times more expensive. An alternative test to serum ferritin is the sTfR, that is not affected by inflammation (Akinsooto et al., 2001), but was nearly five times more expensive.

Figure 8.3: Pictures of branded supplement advertisements



A. Photograph of an advertisement poster that was displayed in one of the study centres claiming their products to be good sources of iron and essential for preventing and managing anaemia for pregnant women; B. Photograph of a branded supplement advertisement showing serving recommendation of 3 scoops of the product per day will meet all their required recommended daily nutrients; C. Photograph of a branded supplement advertisement of their product that it is beneficial for immunity, digestion, growth and development; D. Another advertisement displaying pictures of foods saying consuming a serving of their product provides nourishment equivalent to many natural foods.

Chapter 9

Validation of the BANGLES FFQ

9.1. Background and aims of the chapter

The BANGLES Food Frequency Questionnaire (FFQ) was developed from the Mysore Parthenon FFQ (details on page 64).

An FFQ is used to assess dietary behaviour and quantify the usual intake over a medium or long-term period (Willett, 1998). It can be an appropriate method to study 'diet' as an exposure represented by foods, food groups and diet patterns (Hu et al., 1999). FFQs are relatively economical and easy to use for large populations, compared to other dietary assessment tools such as weighed records, which pose a significant participant burden (Willett, 1998). However, like all dietary assessment tools, FFQs are prone to measurement error, and it is recommended that FFQs are validated to ensure they are accurately measuring the exposure or outcome of interest (Willett, 1998; Cade et al., 2002).

Validation of a dietary assessment tool is defined as the process of determining the accuracy by which the method measures actual dietary intake over a specified time period (Nelson, 1997 & Masson et al., 2003). It is essential for establishing the level and direction of measurement error, grounds of measurement error and means to recognise how these errors can be minimised or accounted for in the analysis (Bellach, 1993). There are two facets of validation that need to be addressed: absolute and relative validity (Cade et al., 2002). Cade et al., 2002 has described absolute validity as 'the measure of agreement between two methods measuring the same variable with the same units'. And relative validity refers to 'the relationship between the measurements of the variable by two different methods, irrespective of the variable units' (Cade et al., 2002). It is challenging to measure absolute validity of dietary intake because of dietary complexity and the lack of a 'gold standard' method. To overcome this inherent limitation, it is valuable to use biomarkers as reference tools to strengthen the validation process (Cade et al., 2017). During validation, the dietary assessment tool to be tested is the 'test tool' and the method with which it is compared, is called the

‘reference tool’. There is no consensus on *the method* of validating a diet assessment tool and it is widely recognised that, none of the existing dietary assessment methods are totally free of error (Cade et al., 2017). In the validation process of the BANGLES FFQ, the FFQ was compared to 24-hour diet recall data, collected at the same visit and blood biomarkers (blood micronutrient levels).

Different statistical techniques explore different facets of validation. For example, correlation is a measure of relative validity and is appropriate to study the direction of associations (Cade et al., 2017). Bland Altman plots define limits of agreement and measure the degree of absolute agreement between the test and reference tools (Cade et al., 2017). It is valuable to use a combination of different methods (Cade et al., 2017; Lombard et al., 2015). In this chapter I describe the methodology and findings of four different approaches to validate my test tool (BANGLES FFQ) against the reference tools (24-hour recall and biomarker data).

9.2. Validation approach 1: Correlations between frequency of intake of food groups measured using the FFQ and 24-hour recall

Aim: To determine whether there is correlation between weekly frequency of food group intake, reported by women using the test tool (FFQ) against the reference tool (24-hour recall).

Method & interpretation: I correlated the daily frequency of intake of foods from the 24-hour recall with the weekly frequency from the FFQ, I used the 21 and 68 food groups described on pages 85 and 193. It is easier to interpret the food groups than the individual 224 foods on the FFQ. I used the dietary data of 510 women from late pregnancy consisting of **an** FFQ and a single 24-hour recall, both collected at the same visit. For the FFQ data, I used the weekly frequency of intake of each food, which was a figure ranging from zero to 30. For the 24-hour recall data, I used the daily frequency of intake of each food, which ranged from zero to five. The Pearson correlation is indicated for relationship between two continuous variables, and the Spearman rho is indicated for assessing relationship involving ordinal variables.

The 21 food group variables constructed using the FFQ and 24-hour recall data were analysed using Pearson's correlation (r) for continuous variables and Spearman's rho (ρ) for categorical variables (≤ 5 categories). The 68 food group variables of FFQ data were continuous, and the food group variables of the 24-hour data were categorical in nature and therefore Spearman's rho was used.

Some validation studies have defined a r or rho of 0.5 and above as a good correlation (Nutritools, 2018; Masson et al., 2003). Because I had only a single 24-hour recall (2 or more is ideal) I lowered these cut-offs and interpreted $r > 0.3$ as a good correlation, $r > 0.2$ as a moderate correlation and $r < 0.2$ as a poor correlation.

Results: Table 9.1 shows correlation coefficients for the 21 food groups. Wholegrain cereals, salads and raw vegetables, fresh fruit, dried fruit and fruit juices, nuts and seeds, milk and dairy products, high sugar products, added sugar and SSB, coffee, nutrient enriched beverage supplements show good correlations, possibly because most of these foods are consumed on a regular basis. Milled cereals, fried and fast food, fish and seafood, egg, poultry, meat, high salt products and visible fat show moderate correlations. Pulses, cooked vegetables, cooked green leafy vegetables, potato containing dishes and potato palya (a side dish) show poor correlations.

Table 9.2 (see Appendix S, page 372) shows the correlations for the 68 food groups. Foods consumed daily such as tea and coffee, tender coconut water, dried fruits, added sugar, cows milk, fermented dairy products such as buttermilk and raita, nutrient enriched beverage supplements, plain boiled white rice, chapathi show good correlations ($r > 0.3$). Foods consumed occasionally or on weekends such as chicken biriyani, high calorie savoury snacks, puff pastry snacks and traditional sweet preparations (including kesaribaath and holige) show poor correlations. But this method captured some occasionally consumed foods such as milkshakes and ice-creams that show moderate correlations. Certain foods such as traditional whole and split pulses show poor correlations, probably because most women in the study did not consume pulses on a daily basis.

Table 9.1: Correlation between the 21 food groups constructed using the 24-hour recall and the FFQ (n=510)

Food group	Pearson's Correlation efficient 'r'/rho
Milled cereals & products	0.22**
Whole grain cereals	0.67**
Pulse and lentil preparations	0.07**
Salads and raw vegetables	0.30**
Cooked vegetables	0.10*
Cooked green leafy vegetables	0.18**
Fresh fruit, dried fruit and fruit juices	0.36**
Nuts and seeds	0.32**
Milk and dairy products	0.54
Fried and fast food	0.16
High sugar products, added sugar and sugar sweetened beverages (SSB)	0.48**
Potato containing dishes	0.17**
Potato palya (potato only dish)	0.11*
Coffee	0.65**
Nutrient enriched beverage supplements	0.35**
Fish and seafood	0.23**
Egg and egg preparations	0.23**
Poultry	0.25**
Meat	0.28**
High salt products	0.27
Visible fat	0.23**

'r' highlighted in red font show good correlations ($r \geq 0.3$), 'r' highlighted in orange font show moderate correlations ($r \geq 0.2$) and 'r' in black font show poor correlations ($r < 0.2$)

* means $p < 0.05$ and ** means $p < 0.01$

Grey coloured boxes indicate the use of the Pearson's correlation coefficient.

9.3. Validation approach 2: Capture of foods consumed daily in FFQ and 24-hour recall

Aim: To determine if foods reported by women as being consumed at least once per day on the test tool (FFQ), are also reported in the reference tool (24-hour recall).

Method & interpretation: If a food was reported in the FFQ as being eaten every day, I would expect it to appear in the 24-hour recall. This analysis was done on the same data as validation approach 1. I created binary variables of commonly consumed foods, indicating whether or not those foods were consumed daily. For FFQ binary variables, weekly frequency values ≥ 7 were assigned a code of 1, indicating consumption of that food at least daily. Then weekly frequency values < 7 were assigned a code of 0. If a food

appeared at least once on the 24-hour recall it was assigned a code of 1, and if it did not it was assigned a code of 0. Next, using these binary variables, the percent agreement scores were computed by using crosstabs and Cohen's Kappa statistic. The Cohen's Kappa statistic value varies from 0 to 1 and is interpreted as follows: 0 = agreement equivalent to chance, 0.1 – 0.20 = slight agreement, 0.21 – 0.40 = fair agreement, 0.41 – 0.60 = moderate agreement, 0.61 – 0.80 = substantial agreement, 0.81 – 0.99 = near perfect agreement and 1 = perfect agreement (Masson et al., 2003; Landis & Koch, 1977).

Results: Table 9.3 shows the percentage agreement between the FFQ and the 24-hour recall in terms of weekly frequency of intake of 26 foods consumed at least daily. Coffee and ragi ball show substantial agreement while tea, milk, fresh fruit juice, green grapes, rice varieties and chapathi show moderate agreement. Also buttermilk, tender coconut water, apple, big and small banana varieties, dates, raisins, walnuts, plain boiled white rice, curd rice, raw cucumber, bread and biscuits show fair agreement. Lastly, pomegranate and guava show slight agreement while lentil sides show poor agreement.

Table 9.3: Percentage agreement between the FFQ and 24-hour recall in terms of frequency of intake of 26 foods (n=510)

Foods	N (%) of agreement		N (%) of disagreement		Cohen's Kappa statistic	Level of agreement based on Kappa statistic ^a
	N (%) reported in FFQ and 24-hour	N (%) not reported in FFQ or 24-hour	N(%) FFQ only	N(%) reported in 24-hour only		
Beverages:						
Tea	110 (74.8)	315 (86.8)	37 (25.2)	48 (13.2)	0.60**	Moderate
Coffee	83 (71.6)	371 (94.2)	33 (28.4)	23 (5.8)	0.68**	Substantial
Milk	312 (95.1)	88 (48.4)	16 (4.9)	94 (31.6)	0.48**	Moderate
Buttermilk	41 (57.7)	368 (83.8)	30 (42.3)	71 (16.2)	0.34**	Fair
Tender coconut water	15 (44.1)	445 (93.5)	19 (55.9)	31 (6.5)	0.32**	Fair
Fresh fruit juice	23 (52.3)	436 (93.6)	21 (47.7)	30 (6.4)	0.42**	Moderate
Fruits:						
Apple	84 (66.7)	272 (70.8)	42 (33.3)	112 (29.2)	0.32**	Fair
Big banana	22 (45.8)	421 (91.1)	26 (54.2)	41 (8.9)	0.32**	Fair
(Robusta)						
Small banana	44 (62.9)	341 (77.5)	99 (22.5)	26 (37.1)	0.28**	Fair
(Yelakki type)						
Pomegranate	6 (33.3)	455 (92.5)	12 (66.7)	37 (7.5)	0.16**	Slight
Guava	4 (22.2)	477 (97.0)	14 (77.8)	15 (3.0)	0.19**	Slight
Green grapes	10 (52.6)	483 (98.4)	9 (47.4)	8 (1.6)	0.52**	Moderate
Dried fruits & nuts:						
Dates	38 (97.4)	331 (70.3)	1 (2.6)	140 (29.7)	0.26**	Fair
Raisins	32 (84.2)	345 (73.1)	6 (15.8)	30 (6.1)	0.23**	Fair
Walnuts	11 (57.9)	461 (93.9)	8 (42.1)	30 (6.1)	0.33**	Fair
Cereal staples:						
Plain boiled white rice	434 (97.7)	11 (16.7)	10 (2.3)	55 (83.3)	0.20**	Fair
Curd rice	10 (40.0)	459 (94.6)	26 (5.4)	15 (80.0)	0.29**	Fair
Rice varieties*	470 (98.1)	8 (25.8)	9 (1.9)	23 (74.2)	0.30**	Moderate
Chapathi	85 (48.3)	300 (89.8)	91 (51.7)	34 (10.2)	0.41**	Moderate
Ragiball	165 (91.2)	272 (82.7)	16 (8.8)	57(17.3)	0.70**	Substantial
Ragi ganji	11 (57.9)	481 (98.0)	8 (42.1)	10 (2.0)	0.53**	Moderate
Vegetables & lentil sides:						
Cooked vegetable palya sides	177 (61.5)	97 (43.7)	111 (38.5)	125 (56.3)	0.05	Equivalent to chance
Lentil sides score	263 (65.8)	43 (39.1)	67 (60.9)	137 (34.3)	0.03	Equivalent to chance
Raw cucumber	19 (63.3)	426 (88.8)	11 (36.7)	54 (11.3)	0.31**	Fair
Snacks:						
Biscuits	53 (51.5)	338 (83.0)	50 (48.5)	69 (17.0)	0.32**	Fair
White bread	14 (29.8)	442 (95.5)	33 (70.2)	21 (4.5)	0.29**	Fair

9.4. Validation approach 3: Comparing the PCA derived diet patterns between the FFQ and the 24-hour recall data

Aim: To determine if similar diet patterns are derived from the test tool (FFQ) and the reference tool (24-hour recall).

Method: PCA was used to explore whether similar diet patterns/components were derived from both the FFQ and the 24-hour recall data using the same 68 food groups (described, table 7.6, page 193). For this analysis, late pregnancy dietary data from 510 women whose FFQ and 24-hour recall were each recorded on the same day, was used (this analysis from step 1 to 5 was done for me by statisticians Sarah Crozier and Matt Johnson at MRC LEU).

The 24-hour recall intakes and the FFQ food frequencies were treated as continuous variables. The FFQ data was presented as weekly values, which were divided by 7 to enable comparison with the 24-hour recall data. Foods that did not appear on the 24-hour recall or FFQ were excluded (leading to 66 food groups).

Step 1, the PCA was run on 24-hour recall data and the first five principal components from analysis were saved.

Step 2, FFQ values were standardised to have a mean of zero and standard deviation of one. A z value was calculated for each FFQ food group using the formula:

$$\frac{\text{Food group FFQ value} - \text{food group 24 hour mean}}{\text{food group 24 hour SD}}$$

Step 3, the first five FFQ component values for each participant were manually calculated using the following formula, taking each component separately:

$$\begin{aligned} & (\text{Food group 1 coefficient 24 hour} * \text{food group 1 FFQ z value}) \\ & + (\text{food group 2 coefficient 24 hour} * \text{food group 2 FFQ z value}) \dots \\ & + (\text{food group n coefficient 24 hour} * \text{food group n FFQ z value}) \end{aligned}$$

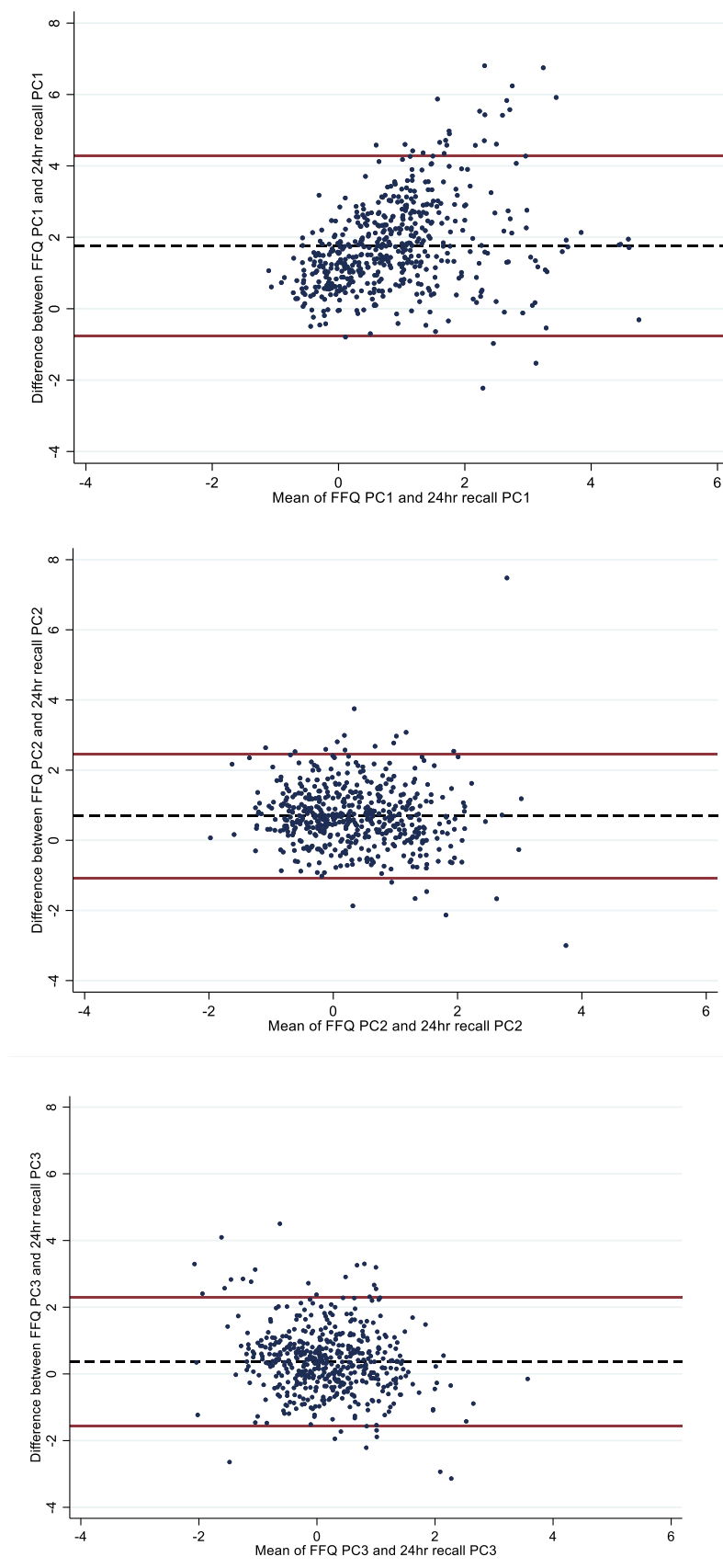
Step 4, the calculated FFQ component values were standardised to the same scale as the 24-hour component values using the formula:

$$\frac{\text{Component FFQ value} - \text{Principal component 24 hour mean}}{\text{Principal component 24 hour SD}}$$

Step 5, in the final step, Bland-Altman (BA) plots were created with the difference between the 24-hour recall and the FFQ component values on the y-axis, and the mean of the FFQ and 24-hour recall component values on the x-axis. The BA plots were used to decide whether there was any systematic difference (bias) between the test and the reference tools, and the extent to which the test and the reference tools agree (limits of agreement). If the two tools agree, about 95 percent of the recordings will be within the upper and lower limits of agreement, calculated as within 2 SD of the mean difference (Bland & Altman, 1986). This method enables assessment of whether the difference between the FFQ and the 24-hour values is the same across a range of intakes (Nutritools, 2018). Additional to BA plots, each of the five component values from the 24-hour recall and the FFQ were correlated with each other using Spearman's rho (ρ); Spearman's rho (ρ) was used because not all the five components were normally distributed.

Results: Figure 9.1 indicates varying levels of agreement between the FFQ (test tool) and the 24-hour recall (reference tool) across the five components. Component 2 showed narrower limits of agreement than components 1,3,4 and 5. Table 9.4 (page 252) describes the correlation between the five components for the 24-hour recall and the FFQ data, using Spearman's rho (ρ). Component 2 showed the best correlation ($\rho = 0.60$) of all components, while the rest of the components 1, 3, 4 and 5 showed weaker, though significant correlations (ρ ranging between 0.29 and 0.46). The PCA of the 24-hour data (described in table 9.5 Appendix T, page 374) describes the characteristics and the possible reasons for component 2 showing narrower limits of agreement than components 1, 3, 4 and 5 and the best correlation. Overall component 2 (compared to rest of the components) showed higher factor loadings for more commonly consumed staple foods.

Figure 9.1: Bland-Altman plots depicting the level of agreement and Spearman's rho (r) for women's diet pattern scores for patterns 1 to 5 (depicted as PC1 to PC5) derived from the FFQ and 24-hr recall data (n=510)



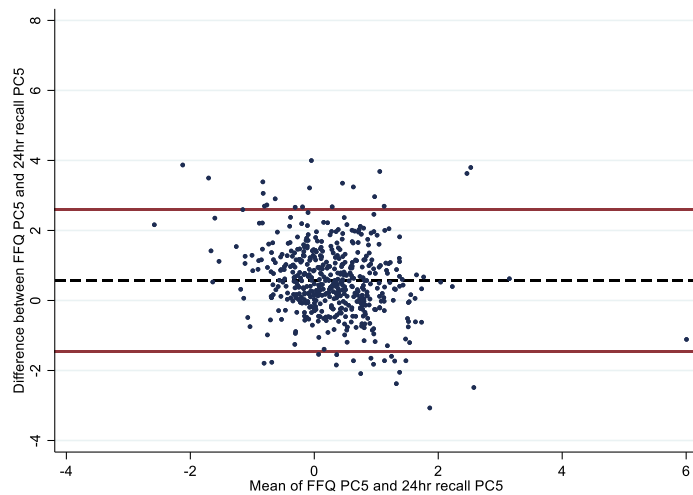
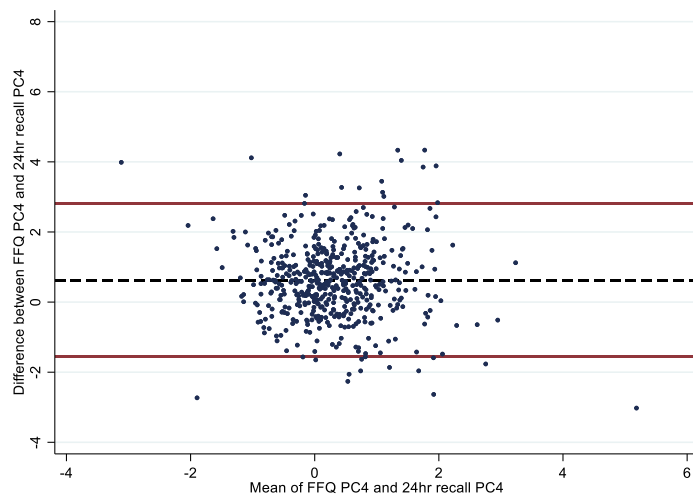


Table 9.4: Correlation between the first five principal components for the FFQ (test) & 24-hour data (reference) (n=510)

Component	Spearman's rho (ρ)	p
First	0.39	< 0.001
Second	0.60	< 0.001
Third	0.46	< 0.001
Fourth	0.34	< 0.001
Fifth	0.29	< 0.001

9.5. Validation approach 4: Associations between intake of micronutrient rich food groups and blood levels of respective micronutrients

Aim: To determine if there is an association between the intake of food groups rich in folate, B12 and iron constructed using the test tool (FFQ), and the reference tool (blood levels of folate, B12 and iron).

Method: I used diet and blood data from 152 women who developed GDM and 152 age and BMI matched controls. In the early pregnancy FFQ (recalled peri-conceptional diet), the test variables used were weekly frequency of intake of food groups rich in folate, B12 and iron. Reference variables were plasma levels of folate, B12 and serum ferritin, collected during early pregnancy.

Foods rich in folate, vitamin B12 and iron were listed (Mahan et al., 2017; FAO 1995 and Watanabe & Bito, 2018) to create dietary intake scores for folate, vitamin B12 and iron. Table 9.6 shows the frequency of intake and sources of foods rich in folate, B12 and iron. Dietary folate score was computed by adding the weekly frequency of intake of cooked green leafy vegetables, pulse and lentil preparations, whole grain foods, dried fruits, nuts and seeds, poultry, egg and egg preparations, fish and seafood and meat. Likewise, the dietary vitamin B12 score was computed by adding the weekly frequency of intake of fish and seafood, egg and egg preparations, poultry, meat and milk and dairy products. The dietary iron score was computed by adding the weekly frequency of intake of cooked green leafy vegetables, dried fruits, nuts and seeds, poultry and meat. The dietary score variables were normally distributed and used as continuous variables. The plasma vitamin B12 and serum ferritin variables were used as log transformed, z-scores (units in SD) and plasma folate as a categorical variable (described on pages 105 - 108). Linear regression was used for vitamin B12 and ferritin, and logistic regression was used for folate, where the normal folate category was used as the reference group.

Table 9.6: Women's weekly frequency of intake of food groups rich in folate, vitamin B12 and iron (n=304)

Food groups	<1/ month	<1/ week	1-2/ week	3 - 5/ week	6-7/ week	>7/ week
Cooked green leafy vegetables ^{a, c}	3 (1.0)	15 (4.9)	76 (25.0)	166 (54.6)	29 (9.5)	15 (4.9)
Pulses & lentil preparations ^a	4 (1.3)	22 (7.2)	40 (13.2)	91 (29.9)	22 (7.2)	125 (41.1)
Whole grain foods ^a	45 (14.8)	38 (12.5)	36 (11.8)	49 (16.1)	38 (12.5)	98 (32.2)
Poultry ^{a, b, c}	68 (22.4)	56 (18.4)	101 (33.2)	75 (24.7)	2 (0.7)	2 (0.7)
Egg and egg preparations ^{a, b}	58 (19.1)	42 (13.8)	71 (23.4)	96 (31.6)	16 (5.3)	21 (6.9)
Fish and seafood ^{a, b}	172 (56.6)	79 (26.6)	29 (9.5)	18 (5.9)	3 (1.0)	3 (1.0)
Meat ^{a, b, c}	138 (45.4)	86 (28.3)	55 (18.1)	20 (6.6)	4 (1.3)	1 (0.3)
Milk & dairy products ^b	2 (0.7)	2 (0.7)	5 (1.6)	14 (4.6)	8 (2.6)	273 (89.8)
Dried fruits, nuts & seeds ^{a, c}	34 (11.2)	35 (11.5)	56 (18.4)	53 (17.4)	21 (6.9)	105 (34.5)

^a Folate rich foods (cooked green leafy vegetables, pulses and lentil preparations, whole grain foods, poultry, egg and egg preparations, fish and seafood, meat and dried fruits, nuts and seeds).

^b B12 rich foods (fish and seafood, meat, poultry, egg and egg preparations, milk and dairy products).

^c Iron rich foods (cooked green leafy vegetables, dried fruits, nuts & seeds, poultry and meat). Information of food groups rich in folate, B12 and iron from Mahan et al., 2017; FAO 1995 and Watanbe & Bito, 2018.

Many women in the study were using synthetic micronutrients at the time of recruitment, such as tablets, nutrient enriched beverage supplements and fortified foods (including ready to eat breakfast cereals and energy drinks like Red Bull) (table 9.7, page 255). Only 11.5% of women were not taking folic acid from at least one of these sources; percentages were higher for B12 and iron. Binary variables indicating using or not using tablets containing folate, vitamin B12 and iron were computed. Nutrient enriched beverage supplements and fortified foods contain all three nutrients of interest (folate, B12 and iron) and binary variables indicating their use or not were computed. Additionally, binary variables for synthetic folate, B12 and iron were computed including use of tablets, nutrient enriched beverage supplements and fortified foods.

Table 9.7 : Number and percentage of women consuming synthetic micronutrients (n=304)

Synthetic Micronutrient source	Consuming N(%)	Not consuming N(%)
B12 tablets ^a	24 (7.9)	280 (92.1)
Folic acid tablets ^a	259 (85.2)	45 (14.8)
Iron tablets ^a	119 (39.1)	185 (60.8)
Nutrient enriched beverage supplement powders ^b	88 (28.9)	216 (71.1)
Fortified foods ^c	27 (8.9)	277 (91.1)
Synthetic B12 in any form ^d	120 (39.5)	184 (60.5)
Synthetic folic acid in any form ^d	269 (88.5)	35 (11.5)
Synthetic iron in any form ^d	180 (59.2)	124 (40.8)

^a Folate tablets contain 5 mg per tablet; ^a B12 tablets contain 500 – 1500 µg per tablet; ^a Iron tablets contain 50 to 60 mg per tablet.

^b Nutrient enriched beverage supplements are flavoured sweetened powders that contain energy, protein and micronutrients including iron, consumed with milk.

^c Fortified foods are natural foods fortified with synthetic folate, B12 and iron and include ready to eat breakfast cereals and flavoured drinks.

^d Refers to women who use any form of synthetic folate, B12 or iron including tablets, fortified foods and nutrient enriched beverage supplements.

I examined the number of women and medians of blood micronutrient levels between women using and not using the synthetic micronutrient sources (table 9.8, page 256). This analysis indicated that women using synthetic micronutrient sources had higher blood micronutrient levels, especially, women using micronutrient tablets (table 9.8). Synthetic micronutrient tablets contain much higher doses of micronutrients than natural foods. Therefore, I excluded the women using the micronutrient tablets from my further analyses of dietary scores of folate, B12 and iron as predictors of their blood micronutrient levels (table 9.9, page 257).

Results: There were 164 women who had normal plasma folate levels (≥ 3 –20 ng/ml) and 140 women who had high plasma folate levels (> 20 ng/ml) (details of data shown in Chapter 8, page 222). In the analysis of plasma folate levels as the outcome, women with normal plasma folate levels were used as the reference group. A higher dietary folate score was associated with higher plasma folate levels, after removing the women using folate tablets from the analysis. The median dietary folate, among women with high plasma folate versus low plasma folate was 22.0 and 16.0 (table 9.9, page 257). From this analysis, we can say that the weekly frequency of folate intake from diet (assessed using test tool FFQ) was associated with folate status (reference tool). However, after removing synthetic folate users from the analysis, the

sample size was very small and so was the effect size (table 9.9). Dietary B12 score did not show an association with plasma B12 levels even after the women taking B12 tablets were excluded from the analysis (table 9.8). The frequency of intake of meat, poultry, dairy and egg did not show an association with plasma B12 levels (data not shown). The weekly frequency of fish intake (≥ 1 -3 times per week) was positively associated with plasma vitamin B12 levels (data not shown). Dietary iron score was not associated with the serum ferritin levels even when iron tablet users were excluded from the analysis (table 9.9, page 257).

Table 9.8: Median values of blood micronutrient levels and number of women using and not using synthetic micronutrient sources

Nutrient intake	Total N	N		Blood micronutrient levels Median (IQR)	
		Using	Not using	Using	Not using
Synthetic folate sources:					
Use of total synthetic folate intake ^a	304	140	200	19.7 (13.1, 20.0)	12.7 (6.0, 20.0)
Use of folate tablets ^b	304	129	175	19.9 (13.1, 20.0)	13.2 (6.3, 20.0)
Use of nutrient enriched beverage supplements ^c (Folate tablet ^b users removed)	304	33	271	15.4 (11.4, 19.7)	12.8 (6.10, 20.6)
Use of fortified foods ^d (Folate tablet ^b users removed)	304	14	290	19.7 (19.3, 19.7)	12.9 (6.20, 20.0)
Synthetic vitamin B12 sources:					
Use of total synthetic B12 intake ^a	304	120	184	359.0 (256.5, 536.5)	343.5 (243.0, 581.8)
Use of B12 tablets ^e	280	24	256	482.0 (338.8, 791.2)	341.0 (237.5, 550.2)
Use of nutrient enriched beverage supplements ^c (B12 tablet ^e users removed)	280	26	254	350.5 (229.0, 652.8)	338.5 (238.5, 546.5)
Use of fortified foods ^e (B12 tablet ^e users removed)	280	77	203	356.0 (247.0, 588.0)	313.0 (223.0, 499.0)
Synthetic iron sources:					
Use of total synthetic iron intake ^a	304	180	124	24.6 (14.7, 36.5)	18.7 (11.3, 33.5)
Use of iron tablets ^f	304	119	185	25.9 (16.8, 36.7)	20.7 (12.1, 34.1)
Use of nutrient enriched beverage supplements ^c	185	55	130	22.4 (13.4, 36.5)	18.8 (11.2, 33.4)

Nutrient intake	Total N	N		Blood micronutrient levels Median (IQR)	
		Using	Not using	Using	Not using
(Iron tablet ^f users removed)					
Use of fortified foods ^d (Iron tablet ^f users removed)	185	9	176	16.8 (8.1, 30.9)	20.9 (12.7 , 35.3)

^aBlood biomarkers: Plasma folate was used as categorical variable with normal folate levels as the reference group and was used in logistic regression models. Results are indicated by an odds ratio; Plasma B12 and serum ferritin were used as continuous variables, transformed and z-standardised, and were used in linear regression models. Results are indicated by the linear regression coefficient β .

^a Total synthetic folate, B12 and iron users refers to women who use any form of synthetic iron including tablets, fortified foods and nutrient enriched beverage supplements.

^b Folate tablets refers to tablets (various brands) that contain high folate doses of 5 mg per tablet.

^c Nutrient enriched beverage supplements are flavoured sweetened powders that contain energy, protein and micronutrients including iron, that are consumed with milk.

^d Fortified foods are natural foods fortified with synthetic folate, B12 and iron and includes ready to eat breakfast cereals, and flavoured drinks such as Red Bull.

^e B12 tablets refers to B12 coming from formulations of iron and folic acid tablets (various brands) that contain high B12 doses of 500 – 1500 µg per tablet.

^f Iron tablets refers to tablets (various brands) that contain high iron doses of 50 - 60 mg per tablet.

Table 9.9: Regression analysis of dietary scores of folate, vitamin B12 and iron from natural foods as predictors of their respective blood biomarkers

Nutrient intake	N included for analysis	Nutrient intake: Median (IQR) of total dietary scores	Nutrient status:			
			Median (IQR) of respective blood micronutrient*	OR*/ β	95% CI	p
Dietary folate score						
Dietary folate score ^a	31*	16.0 (9.8, 19.3)*	9.0 (5.7, 15.2)*	1	-	-
(Folate tablet ^b users removed)	14*	22.0 (14.1, 36.1)	20.0 (20.0, 20.0)*	1.1	1.01, 1.15	0.02
Dietary vitamin B12 score						
Dietary B12 score ^a	277	25.8 (18.0, 35.0)	349.0 (247.5, 552.5)	0.001	-0.009, 0.009	0.97
(B12 tablet ^b users removed)						
Dietary iron score						
Dietary iron score ^a	185	14.5 (8.5, 28.0)	20.7 (12.1, 34.1)	0.01	-0.13, 0.14	0.91
(Iron tablet ^b users removed)						

*Plasma folate was used as a categorical variable and was used in logistic regression models. Results are indicated by an OR; Plasma B12 and serum ferritin were used as continuous variables, transformed and z-standardised, and were used in linear regression models. Results are indicated by the linear regression coefficient. β .

Green text indicates the normal category of plasma folate level ($\geq 3 - 20$ ng/ml) used as the reference group in the regression model and red indicates the high plasma folate category (>20 ng/ml).

^a Dietary folate score includes the weekly frequency of intake of different folate-rich food groups namely, cooked green leafy vegetables, pulse & lentil preparations, wholegrain foods, dried fruits, nuts & seeds, poultry, egg & egg preparations, fish & seafood, poultry & meat.

^a Dietary vitamin B12 score includes the weekly frequency of intake of different B12-rich food groups namely: fish & seafood, egg & egg preparations, poultry, meat and milk & dairy products.

^a Dietary iron score includes the weekly frequency of intake of different iron-rich food groups namely, cooked green leafy vegetables, dried fruits, nuts & seeds, dried fruits, poultry & meat.

^b Folate tablets: 5 mg per tablet; B12 tablets refer to B12 from iron and folic acid tablets that contain 500 – 1500 µg per tablet; Iron tablets refers to tablets (various brands) that contain high iron doses of 50 - 60 mg per tablet.

9.6. Discussion of chapter findings

9.6.1. Summary of findings

The test tool (BANGLES FFQ) was validated using a combination of four approaches against the reference tools (24-hour recall and blood biomarkers). The test tool (FFQ) showed moderate to good correlation, percentage and limits of agreement with the reference tool (24-hour recall). Also the test tool (FFQ) indicating ‘intake’ showed positive association with the ‘status’ of blood folate levels but not with the other blood biomarkers.

9.6.2. The 4 approaches used explored different facets of validation

The first approach, correlation, was used to measure the relative validity (Nutritools, 2018) of the test tool (FFQ) against the reference tool (24-hour recall). There was moderate to good correlation for most food groups. The second approach, percentage agreement using the cross-classification of categories and Cohen’s Kappa statistic, assessed agreement (Nutritools, 2018), for foods consumed and not consumed in both and either of the test (FFQ) and reference (24-hour) tools. This method showed reassuring results for foods that are commonly consumed. The third approach used Bland Altman plots to compare the PCA derived dietary components from the test and reference tools. This validation method tested the limits of agreement (Nutritools, 2018), measuring absolute validity. This analysis found that there were moderate to good limits of agreement between the FFQ and the 24-hour derived components. Overall, component 2 (compared to rest of the components) showed higher factor loadings for the highest number of

commonly consumed staple foods (e.g. milk & rice) and, this is probably a reason for component 2 showing narrower limits of agreement and the best correlation, compared to other components 1, 3, 4 & 5. The other components showed high factor loadings for staple foods, but showed high factor loadings for more less commonly consumed foods which did not appear in component 2 (e.g. pasta, chicken biriyani & sweets). The fourth approach tested the absolute validity where the test tool (FFQ) was compared to a superior reference tool (blood biomarkers) using regression analysis. This approach measured the absolute validity and strength of association (Nutritools, 2018). This analysis found that a higher dietary folate score (intake) was associated with higher plasma folate levels (status). Dietary scores of iron and B12 intake were not associated with their blood statuses respectively, which may be explained by low intakes of iron & B12 rich foods in my sample of women.

9.6.3. Possible reasons for the nutrient intake and status associations

Dietary intake score of folate was associated with plasma folate levels among women in the study, in spite of a small sample and effect size. The possible reasons for this could be that women reported consuming folate-rich food groups such as pulses and lentil preparations, wholegrain cereals and nuts more frequently (table 9.6, page 254). Additionally, a third of women reported consuming poultry and egg and egg preparations between 3-5 times a week. Furthermore, high bioavailability of dietary folate (about 80 percent) could be a possible physiological explanation for the finding (Winkels et al., 2007).

Diet was not associated with B12 status. There could be a number of reasons for this finding. Firstly, women may have used a synthetic B12 source that was not reported. This speculation arises because, the majority (87.5%) of women in the study had normal B12 status (Chapter 8, 8.2, page 222) in spite of a low frequency of intake of B12 rich foods (table 9.6, page 254). Milk and dairy products were the only B12 rich food group that 90 percent of the women consumed daily, more than once in the form of milk, buttermilk and curds (table 9.6). B12 bioavailability from dairy products is considered to be better than poultry, fish or meat (IOM, 1998). But, even with good bioavailability from dairy sources there can be losses attributed to the way we consume milk or curd in India (Samuel et al., 2013). For instance, a glass

of 250 ml raw milk contains about 2 µg of B12 (Watanabe & Bito, 2018). Pasteurisation or boiling of milk (to consume as milk or to make curds) for 5 to 30 minutes reduces its B12-content by 30 – 50 percent, which brings the B12- content to 1 µg (Watanabe & Bito, 2018). Out of this, 50 percent is absorbed in healthy individuals with normal gastric function (IOM, 1998) which means that 0.5 µg of B12 is absorbed. This is less than half of the Indian Recommended Dietary Allowance of B12 per day (Indian Council of Medical Research, 2010; Samuel et al., 2013). Secondly, it is possible that dietary intakes changed from the peri-conception period (the period women were asked to recall in the early pregnancy FFQ (8-16 weeks of gestation), when the blood sample was obtained. There was a gap of 2 – 4 months between dietary assessment and blood collection. The blood status of micronutrients was unaffected by gestational age, a proxy indicator for haemodilution (data not shown). Thirdly, the women may have had unique gut microbiota which could contribute to their B12 status, and which cannot be ascertained from this study. Some bacteria in the small intestine such as *Pseudomonas* and *Klebsiella* may produce significant amounts of vitamin B12 that can be absorbed in the terminal ileum (Albert et al, 1980). Lastly, in spite of biomarkers being superior to other dietary assessment tools, they may not truly reflect dietary intakes due to the unrecorded intake of synthetic nutrient sources. Synthetic sources contain huge amounts of folate, B12 and iron compared to dietary sources. For example, the richest natural dietary source of B12, fish and meat provides between *4 and 20 µg of natural vitamin B12/ 100g* (Mahan et al., 2017), while B12 tablets can provide between *500 and 1500 µg of the synthetic form of B12*. Table 9.7 shows that many women used synthetic sources of folate, B12 and iron and although they were removed from the analysis, we may not have captured all synthetic intakes. A small sample size may also have contributed to the lack of expected dietary nutrient intake-blood status associations. Other Indian studies have shown an association between B12 rich foods and blood B12 levels. A study in Mysore showed associations in children between frequency of intake of B12-rich foods and blood B12 status (Christian et al., 2015); however, children may be less likely to take B12 supplements. Another observational study of 366 pregnant women in Bangalore, found no association between B12 nutrient intake from meat, poultry and milk, but

found that yogurt intake was associated with better blood vitamin B12 levels (Samuel et al., 2013).

The dietary iron score was not associated with serum ferritin levels. Possible reasons for this could be that the women were not consuming enough heme iron, that is the more bioavailable form of iron found in animal foods such as fish, meat and poultry (Hurrell & Egli, 2010). The bioavailability of heme iron from mixed diets containing meat, poultry and fish is about 14-18% while the bioavailability of iron from vegetarian diets is 5-12% among people with no iron stores (Aggett et al., 2012). In BANGLES, close to half of women (45%) reported consuming meat less than once a month and close to a quarter (22%) reported consuming poultry less than once a month. About half consumed non-heme iron sources such as green leafy vegetables (3-5 times per week) and more than a third consumed dried fruits and nuts more than once a day (table 9.6, page 251). There are many dietary factors that influence iron absorption. For instance, polyphenols in tea and coffee and phytates in millets can reduce the bioavailability of non-heme iron. Heme iron is much less affected. Also, absorption of non-heme iron is enhanced by adequate vitamin C intakes (Hurrell & Egli, 2010). There is also evidence that poor Vitamin A, beta-carotene and riboflavin status may reduce non-heme iron absorption (Milman et al., 2008).

9.6.4. Strengths and limitations

The main strength of the validation process is that a combination of methods was used. Additionally, the same units and variables to measure the study exposure 'diet' in my thesis such as weekly frequency of food groups, diet patterns and blood micronutrient levels have been used in the validation process. Table 9.10 (page 264) also shows that the validation guidelines from the consensus checklist of FFQ validation given by Cade et al., 2002 have been largely followed in the validation process.

The biggest challenge in the validation process was in a way, the study-design of BANGLES, because both FFQ and 24-hour recall in first stage of the study were from different reference periods. The reference period in the FFQ for the first study stage was the retrospective diet recall of time around conception (a month before a participant knew she was pregnant), collected in early pregnancy. The reference period in the 24-hour recall was the day

before recruitment in early pregnancy. It was not possible to validate peri-conceptional FFQ data with the 24-hour recall data, since the women may have changed their diets from conception to early pregnancy. However, to address this caveat, I chose the dietary data from the late pregnancy period among the same women of the study for validation approaches 1, 2 and 3.

An important limitation of the validation process that needs to be acknowledged is that it was done after the data was collected. Preferably it should have been carried out before the data collection was started. It would have been ideal if there was no retrospective recall of the 'peri-conceptional diet' in early pregnancy where women would be recruited into the study before their pregnancy. But this study design would have been impossible due to limited time and budget. However, validation with a pilot study in a subset of the study population with three 24-hour recalls and an FFQ could have been possible to do. However, in view of the time constraints that came with the various responsibilities of setting up a large study like this, it was not possible to carry out a prior validation for the FFQ. The validation process was limited by the fact that a single 24-hour recall was available as a reference method for validation, which is sufficient to capture daily consumed foods. But to capture the breadth of foods women generally eat, a minimum of three 24-hour recalls are usually required (Willett, 1998); this was not available in my study. Blood micronutrient data was available for a subset of the sample (n=304) and not the whole sample (n=785). Nutrient estimations of folate, B12 and iron in foods, which was not done, may have shown stronger associations with blood levels of these micronutrients.

9.6.5. Conclusions

The BANGLES FFQ (test tool) showed reasonably good relative and absolute validity with the reference tools, across 4 approaches used for commonly consumed foods.

Overall, taking into account the correlation and kappa methods, I have demonstrated that the BANGLES FFQ is a valid method to assess the dietary frequency of intake of most food groups. My results suggest that intakes of the most frequently consumed foods are most accurately captured. These include milled cereal products (including rice preparations), wholegrain

cereals (including individual wholegrain cereal components such as unpolished rice, chapathi and millet preparations such as ragi ball, ragi ganji), raw vegetables, fruits, nuts and seeds, milk and dairy products, high sugar products, coffee, fish, egg, poultry, meat and visible fat sweet snacks including biscuits. It makes sense that these foods are accurately reported as it is often easier for respondents to remember and report foods that they frequently consume. In addition, foods that are eaten daily are much more likely to be reported on the 24-hour recall, whereas those eaten less frequently e.g. pulses and cooked vegetables will not necessarily be reported during the 24-hour recall.

Based on this analysis, it is considered as an appropriate tool to assess dietary intake among reproductive-aged women in South India.

Table 9.10: Checklist of selected FFQ validation guidelines from the consensus document adapted from Cade et al., 2002 and my study analysis responses

Consensus recommendations on validation from Cade et al., 2002:	Checklist responses in my study analysis:
Sample size:	
The subjects recruited for the validation study should be representative of the main study target population.	Yes, validation used the same study population.
Time frame of reference method in validation studies:	
The period of assessment should be the same for both test and reference methods.	Yes, both test tool (FFQ) and reference tool (24-hour recall) were used for validation and were collected on the same day in late pregnancy (data used for approach 1, 2 and 3). Here, the FFQ referred to a period of a month, while the 24-hour recall was a single day. In the analysis for approach 4, I used the peri-conceptional diet FFQ data which was collected in early pregnancy at the same time as blood sample collection. However, there was a difference of 2-4 months between the food intakes being recalled for the test (FFQ) and the reference methods (blood micronutrient levels).
Exposure in the reference and validation study:	
The methods of validation must take into account the purpose of the food-frequency questionnaire. For example, all foods and nutrients to be assessed in the main study should be assessed.	Yes, the same foods and food groups were used for both the test (FFQ) and the reference (24 hr recall) methods. But for approach 4, nutrient levels in dietary data was not estimated (since the purpose of the FFQ was not to assess single nutrient status). Dietary scores created by summing the frequency of intake of folate-, B12- and iron-rich foods were used to compare with the blood levels,
Recommendations on selection of dietary method for validation studies:	
Using more than one approach to validation gives added credence to the results.	Yes, a combination of 4 approaches, namely correlation, percentage of agreement using Cohen's Kappa statistic, regression and Bland Altman plots have been used.
Recommendations on use of biomarkers in validation studies:	
Consider carefully what is being measured. Take into consideration the relevant time frame, and relationship between biological variation and variation in dietary intake	Yes, considered. Assessment of diet exposure preceded the outcome of biomarkers measured, which preserved temporality. But there was a difference of 2- 4 months between the time diet was assessed and blood was collected. The peri-conceptional diet was retrospectively recalled in early pregnancy when the blood sample was collected.

Consensus recommendations on validation from Cade et al., 2002:	Checklist responses in my study analysis:
Recommendations on correlation, regression and the Bland – Altman plots (BA plots) in validation studies:	
The methods developed by Bland and Altman should be used to measure the agreement between food-frequency questionnaires and other measures of dietary intake.	Yes, BA plots have been used to measure limits of agreement between the test (FFQ) and the reference (24-hour recall) tools.
These methods should be used in context and interpreted in the light of the target population and what the acceptable levels of bias and limits of agreement are in this context.	Yes, the methods used have been interpreted in the light of target population, described in discussion in section 9.6.
Regression or correlation may be used in conjunction with the Bland – Altman method.	Yes.
If correlation is used, Pearson's correlation should be used for normally distributed data, Spearman's correlation for non-normally distributed data.	Yes, used accordingly in section 9.2.
Kappa and/or sensitivity, specificity, etc. may be appropriate if the data are ordered categorical or binary.	Kappa statistics were used for binary variables, described in section 9.3, for approach 2.
Recommendations on sample size for validation studies:	
Expert statistical advice should be sought to estimate required number of subjects. If resources are available, higher numbers of subjects will provide better estimates of reproducibility or validity. A sample size of at least 50 to 100 subjects for each demographic group is recommended.	Yes, statistical help was sought for the power calculation of sample size for the main study, data from which was used for validation. The sample size for validation approaches 1, 2 and 3 was 510. The sample size for approach 4 was smaller (n=45) after removing synthetic folate tablet users.
Details on description of FFQ in utilisation studies:	
Was the BANGLES FFQ utilised from a previously validated FFQ ?	Yes, the BANGLES FFQ was modified for the study of pregnant women's diet from the 136-item FFQ of Mysore Parthenon study, used to assess children's diets. Mysore is a city in the same state (Karnataka) as Bangalore. The Parthenon FFQ was validated with the biomarkers (Kehoe et al., 2014).

Chapter 10

Final Discussion

- My analysis of the frequency of intake of food groups showed that, after correcting for multiple testing, none of them were significantly related to the risk of developing GDM. The finding, at the traditional significance level of $p < 0.05$, that a higher frequency of intake of wholegrain cereals, pulses, and nuts and seeds was associated with a lower risk was consistent with previous literature. The finding that more frequent intakes of eggs, and of fried and fast foods, was associated with a lower risk, was unexpected.
- I derived diet patterns using Principal Component Analysis. This identified five distinct patterns: 1) High-diversity, urban, 2) Rice-fried snacks-chicken-sweets, 3) Healthy, traditional vegetarian, 4) Snacks, sweets and takeaway preference and 5) Unpolished rice-fish-vegetables. All of these contained both 'healthy' and 'unhealthy' foods, except pattern 3. At the traditional significance level ($p < 0.05$) the high-diversity urban diet pattern was associated with a lower GDM risk in one model, after adjusting for a priori confounders. However, after adjusting for BMI and correcting for multiple testing, none of the patterns were significantly associated with the risk of developing GDM.
- Women with low serum ferritin levels in early pregnancy had a lower GDM risk, than those with normal ferritin levels. There were no associations between vitamin B12, folate or vitamin D levels in early pregnancy and GDM.
- Women taking iron and calcium+vitamin D supplements in early pregnancy, compared with non-users of these supplements, had a higher GDM risk. There is previous literature supporting an association of iron supplements with an increased GDM risk.
- A higher BMI in early pregnancy, a proxy for greater adiposity, was a strong independent predictor of GDM risk, and none of the other socio-demographic and lifestyle variables were significantly related to GDM

after controlling for BMI. Adjusting for BMI also attenuated the weak association between the high diversity urban diet pattern and GDM, suggesting that any effect was mediated by BMI.

My study does not provide strong evidence that specific dietary components or diet patterns are related to the risk of GDM among Indian women. It is possible that higher intakes of wholegrain cereals, pulses, and nuts/seeds are protective, and this is the first evidence in an Indian context. However, this requires confirmation, both in my own data using quantified intakes and from future larger studies covering a greater diversity of Indian diets. These food groups contain multiple micronutrients and it is not possible to attribute health benefits to any specific nutrient. Wholegrain cereals are rich in fibre, B-vitamins, antioxidants and minerals including iron, zinc and magnesium. Pulses and legumes are rich in protein, folate, soluble and insoluble fibre, iron and phosphorous. Nuts and seeds are rich in healthy fats (PUFA, MUFA, omega-3 fatty acids and saturated fatty acids), fibre, vitamins and minerals. Eggs are sources of phospholipids, protein, B-vitamins particularly B12 and choline, vitamin A and antioxidants including lutein and zeaxanthin (Mahan et al., 2017). Different micronutrient rich food groups in a diet may offer a 'cocktail of different nutrients', that may be beneficial to prevent GDM.

The study also provided some evidence in an Indian context that eating a diversity of different foods may be associated with lower GDM risk. Comparing the analysis of food groups and diet patterns, the same food groups that were associated with a lower GDM risk were components of the HDU pattern. Although, the HDU pattern also contained unhealthy foods, women may have had these in limited quantities. For instance, women above the highest quintile of the HDU diet pattern had a median frequency of intake of biscuits and cakes of two times per week. This may imply that a diversity of protective food groups including wholegrain cereals, pulses and legumes, fruits, vegetables, greens, milk, egg, chicken and meat on our plates may be beneficial to prevent GDM. This is consistent with recent reports that suggest that diet diversification using the above food groups benefits health and prevents chronic diseases among Indians (What India eats report - ICMR-NIN, 2020 & Sharma et al., 2020). However, further work on diet patterns, for example a) a more quantitative analysis and b) by exploring patterns based on current knowledge to derive 'healthy' eating indices, may

be useful. BMI may be a mediator of diet pattern effects on GDM, that is, in the causal pathway of diet leading to GDM, since any evidence of diet pattern-GDM associations in my study, including the association between the HDU pattern and GDM, were observed only when BMI was absent from the models. Adjusting for mediators is known to weaken associations between the exposure and the outcome (Vanderweele, 2015). The few studies that have treated BMI as a mediator report that the lower GDM risk associated with healthy diet patterns such as Mediterranean diet, could be mediated through effects of BMI (as a marker of adiposity) on insulin resistance (Schoenaker et al., 2016b). Hence, it is clear that helping women to achieve a normal body weight before entering pregnancy is an important public health objective; and a healthy diet and physical activity are key to achieving a healthy pre-pregnancy BMI.

My study suggests that taking iron supplements in early pregnancy and having higher iron (ferritin) status, may contribute to GDM risk. This too requires further investigation, because iron supplements are an accepted and longstanding practice shown to reduce/prevent anaemia, and it would be a big step to question their routine use. Intervention studies may be not feasible until future Indian observational studies explore associations between ferritin and GDM, and also try to disentangle the roles of iron status or inflammation or both in GDM.

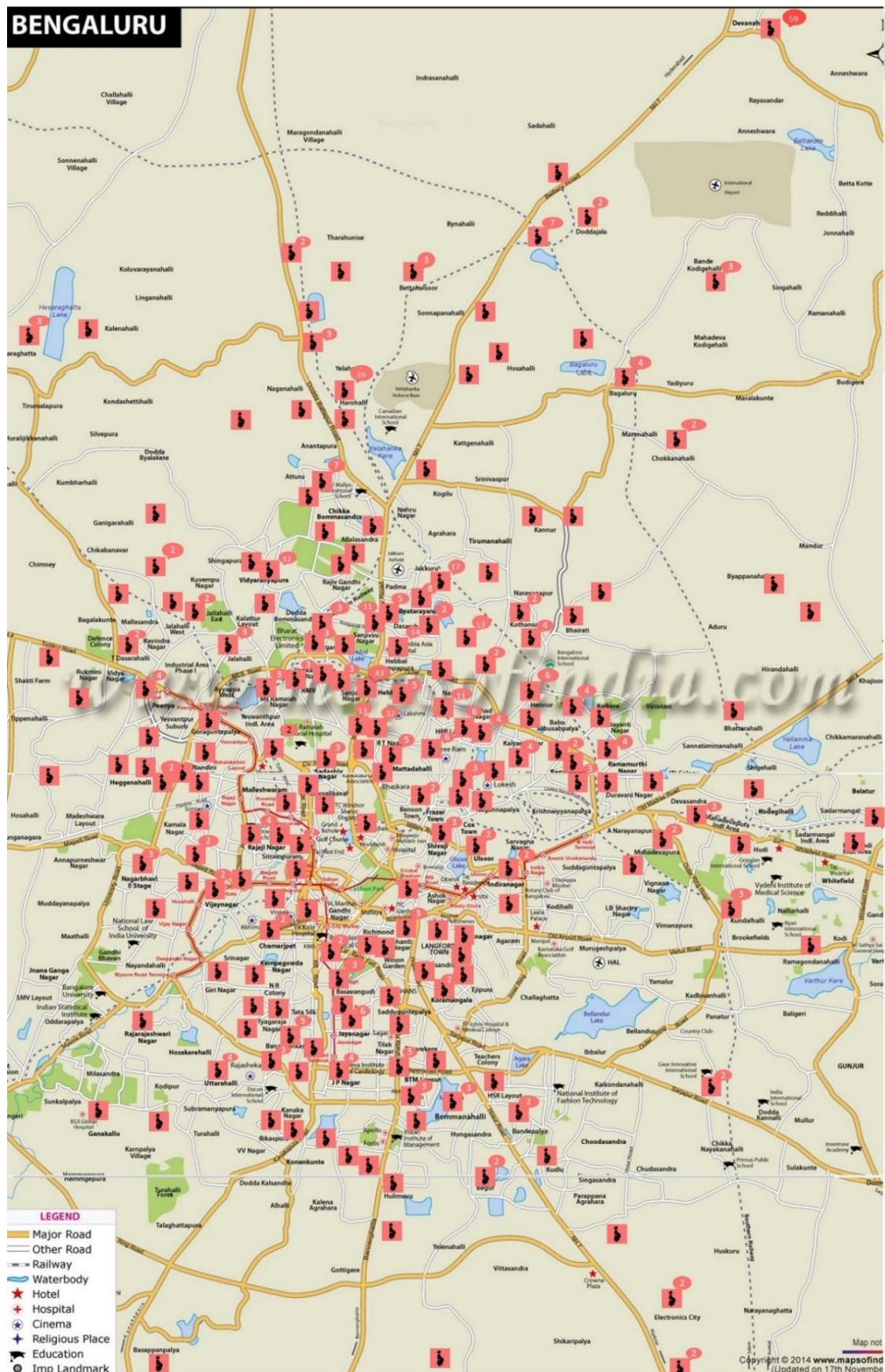
10.2. Study strengths and limitations and validity of study findings

Strengths: This is the first study investigating the association between peri-conceptional intake of food groups, diet patterns, blood ferritin levels and iron tablets and GDM risk in India. We followed a sampling system whereby every woman attending antenatal clinics was approached in Baptist hospital and in Cloudnine, all patients of the collaborating obstetrician, without prior bias. Study exclusion/inclusion criteria were limited to women not having any prior diabetes and singleton pregnancies. This ensured that the exposure (diet) being measured was not affected by a previous diagnosis of diabetes. These design features make the findings relevant to a larger population. Diet as an exposure was assessed using an FFQ that was

customised and validated in the same study population and administered by trained nutritionists. Additionally, we used an FFQ kit with familiar household vessels and a food atlas with illustrations of all the foods, making them easily identifiable by participants. Blood micronutrient levels were analysed at a well-known research laboratory that has standardised the analysis of folate, vitamin B12, ferritin and vitamin D measurements in India. A large sample size of 785 women, representing different parts of Bangalore (figure 10.1, page 271) were recruited in early pregnancy, out of which 714 (91%) were followed up for glucose tolerance. The OGTT was done by trained lab technicians who complied with international standards of laboratory practices. Various co-variables associated with the exposure 'diet' and the outcome 'GDM' such as age, BMI, health details including family history of T2DM, SES, area of residence, family type, physical activity were assessed. Reliable sources including national identity cards (Aadhar) were used for collecting information on age and address. Statistical modelling addressed confounding, inherent in an observational study by adjusting for data-driven and a priori confounders that included age, gravidity, family history of T2DM, urban/rural residence, family type, supplemental use, including folate, iron, calcium-vitamin D, B12, energy-protein supplements and physical activity. Few studies have addressed confounding comprehensively, especially taking into account the use of nutrient supplements. The study also used rigorous criteria to address multiple testing, which few studies investigating diet-GDM have done before.

Limitations: We recruited 785 out of our target sample size of 1000 women owing to my PhD timeline. Ninety-five percent of the 714 study participants had a 75-gram GTT and about 5 percent had a 50 gram GCT, based on the clinical decisions of obstetricians. It is unlikely that these 5 percent contributed to substantial changes in the findings. An OGTT is a robust technique for screening women for GDM, but studies have found only small differences between an OGTT and a GCT in identifying GDM (Anjanakshi et al., 2009). The study exposure was a recall of diet around conception assessed in early pregnancy, but there is evidence to support that diet patterns are reasonably stable from before pregnancy to during pregnancy (Crozier et al., 2009). Information on early life risk factors for GDM, such as the women's birthweight, was not possible to assess, as most participants

Figure 10.1: Participants of BANGLES represented on the map of Bangalore based on their area of residence



had not preserved their birth records. One of the study hospitals did not cater to the medical needs of very low-income groups and hence our study population did not have a very good representation of them, although women with a wide range of SES were included.

Women with lower SES may have more micronutrient deficiencies and would have contributed to more variation, thus increasing chances to detect micronutrient-GDM associations for folate, B12 and vitamin D, which were not observed in the sub-sample of 300 women we analysed. It would have been interesting to observe the potential role of BMI as a mediator, if more than 10 percent women in the study were underweight. Other Indian studies have emphasised the higher risk of the 'thin-fat' Indian phenotype for GDM and T2DM (Fall, 2013 & Yajnik et al. 2010). My study did capture the diversity in diets with women from different SES; nonetheless, more women from very low-income groups could have increased the variability in diets, and therefore the chances of detecting dietary differences between women who did and did not develop GDM. Studies have shown that women from very low-income groups such as urban slum-dwellers consume less milk, fruits, vegetables and meat (Chopra et al., 2012).

Validity of the study findings:

- a. **Sample representativeness:** My study sample was representative of the Bangalore/Indian population with respect to some key population characteristics. Women belonging to different religions, urban and rural areas, nuclear and joint households, age groups, and BMI participated in the study. A third had a family history of T2DM, and 10 and 20 percent of women had PCOS and hypothyroidism respectively. Many urban women have these health concerns in recent times (Goyal et al., 2019). There were more primigravid (70%) than multigravid women in the study, similar to the proportions seen in my study hospitals. Ninety percent of women attending Cloudnine and 65% of women attending Baptist are primigravid (estimated from Obstetric records). India is a relatively young population with a mean age of 29 and more than half are below 25 (United Nations, 2019). Commonly, urban women delay marriage and childbearing to focus on their education and career, and the average family size has reduced from 5 to 2 in the last three decades (NFHS 4, 2014-15).

My study was less representative of the overall Bangalore population with respect to socio-economic status. Because I was not able to include a large government hospital, Vani Vilas Hospital, my study had less representation from women of the lowest socio-economic status and least educated women. Although the majority of women belonged to the higher SLI levels (based on the NFHS-2 classification), women had varying SLI scores, and income-wise, were representative of the lower and middle-income groups in India. For instance, 40% of study women's income ranged from INR 10,000 - 30,000, close to the estimated average income in Urban Bangalore of INR 30,000 and in India as a whole of INR 11,000 (World Bank, 2020). SLI is a comprehensive SES indicator, but the classification available (NFHS 2, 1998 – 99) is twenty years old and requires updating based on inflation. Women of very low SES were less represented in the study, nonetheless, women from a range of SES were included. This was observed from SES-defined-differences in the exposures. For instance, expensive foods (page 140 & 142) and blood B12 status (page 227) were positively associated with SES.

- b. **Bias:** Response bias, potentially caused by intra/inter-observer differences in interviewing techniques, was minimized by the development of a protocol for the collection, measurement, and interpretation of dietary information and tools such as an FFQ kit accompanied by manuals and an FFQ atlas, training the nutritionists and conducting an IOV study. However, sometimes women with a high BMI may under-report food intakes, which is challenging to overcome. Selection bias (due, for example, to systematic differences in the study sample selection), although this cannot be completely overcome, was minimised by a consecutive sampling technique, by approaching all women in the antenatal clinic in an unbiased way. Detection bias (systematic differences in outcome assessment) was addressed by running a sensitivity analysis with and without women diagnosed using less stringent methods than the full OGTT, such as the GCT. Attrition bias (systematic error generated by differences in participant follow-up) was likely to be minimal as 90% of the women were followed for an OGTT. There were no significant differences in key characteristics, including age, SES and BMI among women who were followed for an OGTT and those who dropped out (tested, page 128).

Social desirability bias (favourable responses by women in line with known healthy diet perceptions) was minimized by explaining to the women before the data collection that their actual diet assessment was important to enable us to advise them on healthy eating during their pregnancy.

- c. **Confounding:** Confounding is a major issue in any observational study. I used two approaches to address this. After reviewing the literature to determine variables that could potentially be confounders, I adjusted for those that were both associated with my exposures and with GDM (the 'data-driven' approach) and for all the confounders derived from literature review regardless of whether they were related to both exposure and outcome in my own data (the '*a priori*' approach). The findings were similar with both approaches.
- d. **Multiple testing:** Correcting for multiple testing is an important method for avoiding false positive findings, although they are also known to increase false negative findings in observational research. I used a strict method for doing this in my study, and none of the dietary measures were significantly related to GDM after making these corrections. Statistical significance results from the strength of an effect and the sample size, and it is increasingly recognised that having a single cut-off for significance is arbitrary to some extent. Therefore, on balance the observed findings, shown for the first time in an Indian context, were consistent with current global advice to increase diet diversity and eat wholegrain rather than refined cereals, and include intakes of nuts, seeds, egg and pulses as part of a balanced diet.

10.3. Public health relevance of study findings and available evidence for India

10.3.1. Encouraging women to attain a healthy pre-pregnancy BMI

In BANGLES, the overall GDM prevalence was about 22% among women with a range of BMI (underweight: 10.5%; normal: 54.1% & overweight-obese: 36%). Future Indian national health programmes should emphasise the importance

of attaining a healthy BMI before and during pregnancy. GDM is often identified in late pregnancy but the source of metabolic dysfunction is likely to be established much before conception and probably, according to Barker's hypothesis, when the woman was a developing foetus. While a healthy diet and exercise may be beneficial for pregnant women at risk for GDM, these practices are often initiated after the 1st trimester which may be too late. Being overweight or underweight increases GDM risk (Catalano, 2014). The importance of a healthy BMI for maternal metabolic health and pregnancy outcomes, including reducing GDM risk and improving long-term offspring health, has been emphasised by many studies (Catalano et al., 2014; Najafi et al., 2019; Buffarini et al., 2019 and Barker et al., 2018) and health authorities (Public Health England, 2012; World Diabetes Foundation 2012 and International Federation of Gynaecology and Obstetrics, 2015).

10.3.2. Public awareness of healthy diverse diets and the need for intensive education

A healthy diverse and balanced diet may be critical for attaining a healthy BMI (WHO, 1990; Ruel et al., 2003), but before that an awareness of what constitutes a healthy diet is essential, which may be low in India (Misra et al., 2009; Sharma et al., 2020). For many, awareness may not influence their diet for economic, cultural or religious reasons (Green, 2016). Evidence for this emerges from dietary pattern studies in India in which no clear healthy or unhealthy diet patterns have been identified (Green, 2016; Kehoe et al., 2014). Although my study identified one healthy vegetarian pattern, the other diet patterns had both healthy and unhealthy components. This is unlike the Western countries (e.g. UK or USA), where clear healthy and unhealthy diet patterns have been identified using data-driven methods (Newby et al., 2003), possibly due to better awareness about healthy versus unhealthy foods. Also, in India, many foods cannot be classified clearly as healthy or unhealthy, for example, vegetable pulao rice contains white rice (less healthy than brown rice), but also contains healthy vegetables and spices. Globally, common features of healthful diet patterns, associated with a healthy BMI and reduced GDM and T2DM risk include a high intake of diverse food-groups. Most of this knowledge has been derived from Western populations. However, recent data from across India show that a large majority of Indians have sub-optimal dietary diversity (Willett et al., 2019,

What India eats report – ICMR-NIN, 2020 & Sharma et al., 2020), eating too much cereal-based food and not enough fruits, vegetables, pulses and legumes, milk, nuts and seeds, eggs, poultry, meat and fish. These trends are observed in urban and rural areas across different regions in India (What India eats report – ICMR-NIN, 2020). These reports also highlight that public awareness and intensive education programmes in India across SES are critical to achieve diet diversification to prevent chronic diseases (Sharma et al., 2020).

10.3.3. Increasing fruit and vegetable intake and diversity

In India there has been no emphasis at a national level on increasing fruit and vegetable consumption, for the population. There is no equivalent of the ‘5 a day’ campaign airing on radio, television and newspapers. My study did not detect any association between fruit and vegetable intakes and GDM risk, but there is convincing evidence globally that sufficient quantities and diversity of fruit and vegetables are vital for health and chronic disease prevention (WHO, 2003). The FAO/WHO recommends a daily intake of five or more 80 gram servings (400g per day), excluding tubers such as potato (WHO, 2003). This is the best available recommendation until we have robust Indian data. Therefore, it is worthwhile to deliver this message to the masses. In my study, although median fruit consumption frequency was 23.5 servings/ week, the intake of vegetables was low. The median weekly frequency of intake of cooked vegetables was 9.5 and cooked greens was 3, corresponding to approximately *86 grams per day*. If this is the scenario among the middle and higher income groups, the intakes among lower income groups may be much lower. A study of 100,000 Indian households reported that daily per capita household fruit and vegetable intake was *as little as* 15 and 145 grams respectively for rural India, and 29 and 155 grams respectively for urban India. Potato and banana dominated intakes, indicating a low diversity of intake (Minocha et al., 2018). There is an urgent need for the government to initiate nation-wide health promotion messages to increase the intake and diversity of fruit and vegetables, in regional languages, based on availability (figure 10.2, page 277) (Government of India, 2014). Also, improving their affordability could improve intakes (Kehoe, 2017; Minocha et al., 2018).

10.3.4. Diversifying the existing Public Distribution System (PDS)

India's Public Distribution System (PDS) is one of the largest in the world (Sekher et al. 2017) and has the power to influence the dietary quality of millions of Indian households. The PDS provides white rice, wheat and sugar at subsidized rates *as low as INR 2/kilogram*, covering 70 percent of rural India and 50 percent of urban India (Ecker & Nene, 2012). Households using the PDS have lower dietary diversity and quality, as they mainly consume cereals and less pulses, milk, fruits, vegetables, nuts and meat, than households who do not use the PDS (Niti Aayog report 2016, Government of India). In spite of this, millions of rupees of public money are still being spent on a cereal based PDS, when there are unmet needs for other food groups.

The green revolution, large-scale milling (removal of outer layers of bran and germ rich in B-vitamins and other nutrients, leaving the starchy endosperm, which raises plasma glucose levels rapidly), high crop subsidies leading to cheaper and more widely available white rice and wheat have all increased the consumption of refined cereal grains, with reduced nutrient-content. This has limited the intake of wholegrain cereals such as unpolished rice, barley, rye, maize, and millets including sorghum/jowar, pearl millet/bajra, ragi/finger millet etc. (Sekher et al. 2017 & Raju et al., 2018). Rice is a staple part of South Indian meals. Presently, the PDS distributes *double-milled-white rice* that rapidly raises plasma glucose. The traditional south Indian diet consisted of unpolished under-milled, brown rice, that has now been replaced by polished white rice. The milling was done mainly to reduce storage losses; as white rice was more pest-resistant than brown rice. Global evidence suggests that shifting the balance from refined to wholegrain cereals will improve nutrient and fibre intakes and have a beneficial effect on health outcomes, including diabetes. A valuable measure could be to introduce brown rice in the PDS with better shelf-life and pest-control technology (FAO, 2018). Education about the health benefits of brown rice and its traditional importance may be essential to revive its consumption, since people prefer white rice for taste and familiarity reasons. Millets are native to India and the revival of millets as staples, along with unpolished rice and whole wheat, could be beneficial in preventing non-communicable diseases (Raju et al., 2018, Sharma et al., 2020). Millets are nutritious

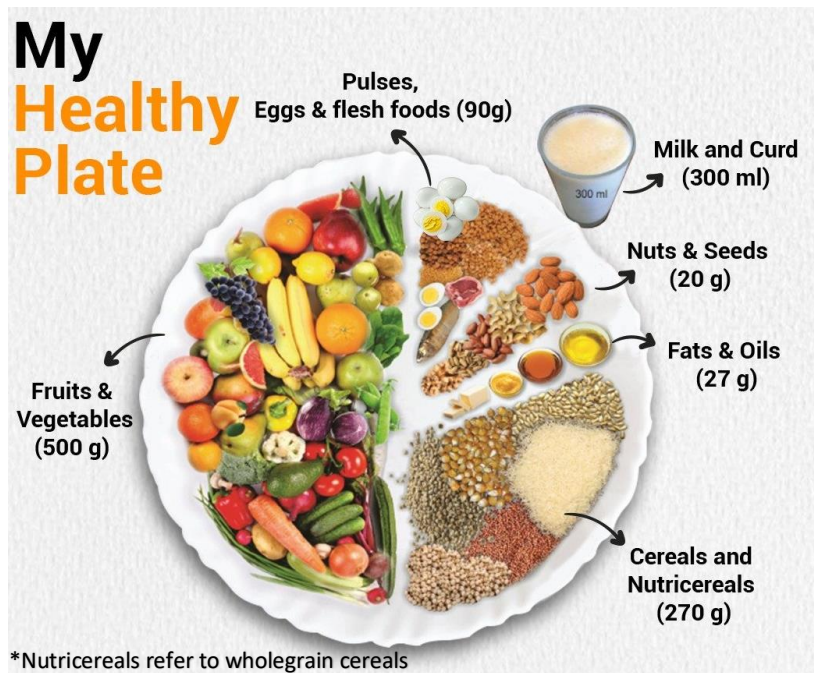
cereal grains, rich in iron, phosphorus, B-vitamins, calcium, potassium, magnesium, zinc and fibre. (Devi et al., 2014a). Millets are not refined before consumption, and the flour is consumed with the outermost layers intact. The feasibility of including millets in the PDS should be assessed.

Additionally, agricultural incentives for farmers in states like Karnataka, Orissa and Maharashtra have revived their consumption, which may be a lesson for policy action across India (Raju et al., 2018). National dietary guidelines recommend that a healthy vegetarian adult needs to consume 80 grams of pulses per day (Dietary Guidelines for Indians, 2011), but actual intakes are less than a third of this recommendation (Minocha et al., 2017). In my study, the median weekly frequency of intake of pulses and lentils was 4 (average intake of 200 grams per week or 30 grams per day), again lower than recommendations. The government has theoretically included pulses in the PDS, but nothing has been implemented, except in some states such as Tamil Nadu, Telangana, Andhra Pradesh and Chhattisgarh (Rampal, 2018). It could be worth-while considering the extension of these programmes for the whole country (Swaminathan et al., 2012).

While a balanced and diverse diet, including fresh fruit and vegetables, wholegrain cereals, pulses and legumes, nuts and seeds as recommended in the Indian dietary guidelines, plays an important role in achieving and maintaining a healthy BMI, my study did not provide strong evidence linking these or other specific foods, or diet patterns, to GDM risk. The study cannot therefore lead to additional specific recommendations regarding the prevention of GDM through diet at this stage.

10.3.5. Challenges in achieving diet diversification in low resource settings and possible novel food-based approaches

The new Indian dietary recommendations suggest to increase diet diversification from different food groups (figure 10.3, page 280). However, what does this ‘balanced diet’ mean? and is it practically achievable across a range of SES? (Rao et al., 2018). For one to achieve the suggested ‘balanced diet’ recommendations, it may cost a minimum of INR 15,000/month (GBP 148) for a family of four. This is possible for higher SES, challenging for middle SES and nearly impossible for lower SES (a majority).

Figure 10.3: My Plate for the Day, 2020 (ICMR-NIN, 2020)

Worrying figures show that, a mere 9% of rural and 14% of urban Indians consumed recommended amounts of milk / curds and vegetables (What India eats report – ICMR-NIN, 2020). In this scenario, where there is a high GDM prevalence and a large population of 1.3 billion - novel, low-cost, food-based approaches may be useful. For example, the SARAS study showed that culturally appropriate micronutrient-rich snacks (with greens, fruit and milk) may be useful for the lower income groups given pre-conceptionally to prevent GDM (Sahariah et al., 2016). The daily cost of this micronutrient rich snack was estimated at INR 5 (GBP 0.05) (Shivshankaran et al., 2019). This amounts to INR 2250 (GBP 22) per reproductive-aged woman for 450 days (6 months of pre-conception and 9 months of pregnancy). This amount may fit well within the budget of current national schemes such as the Pradhan Mantri Matru Vandana Yojana that offer cash transfers of INR 5000 (GBP 50) for pregnant mothers (PMMVY, 2017). In most of these schemes, the cash reaches the women 6 months after child birth. These policy gaps make an important case for us researchers to convey potential policy resets for policymakers, to consider the importance of nutrition during the pre-conception period and beyond.

10.3.6. Synthetic micronutrients

In my study, higher serum ferritin, and use of iron tablets, in early pregnancy was associated with an increased GDM risk. These are observational findings

and cannot determine causality. There is growing observational evidence from other studies showing associations of higher iron status and/or use of iron supplements with an increased risk of GDM (details, 8.9.4, page 237 - 238), however further research is needed. Additional observational studies in the Indian population would be valuable. Randomised controlled trials of iron supplements, or different doses of iron supplements would be informative, where this can be done ethically, but would be difficult in India – until we know the minimum iron requirement for a healthy pregnancy. Studies exploring possible mechanisms linking iron status with glucose intolerance, including the use of animal models, would also be informative. I find it concerning that many women consume self-prescribed synthetically manufactured nutraceutical tablets, supplements and fortified foods. Public awareness of the potential harmful effects of consuming unnecessary excess synthetic nutrient supplements may be useful and marketing of these may need to be regulated.

10.3.7. Physical activity

In BANGLES, there was no association between women's reported physical activity levels and GDM. However, it was concerning that the majority of women did not meet the moderate-intensity physical activity (PA) recommendation of 150 minutes per week (RCOG, 2017 & WHO, 2010), since only 19.5% did more than 150 minutes of weekly light walking. While interviewing the women, they reported that family members advised them to rest during pregnancy. A study found that 71.2% of urban Indian women were physically inactive (Anjana et al., 2014). There is evidence from other studies which indicates that PA before and during pregnancy is associated with a lower GDM risk (Tobias et al., 2011). PA improves muscle's glucose uptake, reduces oxidative stress, improves endothelial function, decreases fat mass and increases muscle mass, which all improve blood glucose control (Jeon et al., 2007). In view of the evidence, public health messages should emphasise the importance of PA before and during pregnancy, and address cultural barriers that physical activity during pregnancy is not harmful, but indeed beneficial.

10.4. Personality enhancement, life skills learnt and expansion of core specialist knowledge

My PhD journey has been intellectually fulfilling and has taught me invaluable skills for life. Identification of a knowledge gap important to my home country's public health, proposal and protocol development, designing study tools, acquiring funding and implementing the study have solidified my independent thinking and drive. Working under tight timelines to run clinics, collect data, samples, reading and writing my thesis have taught me discipline. I presented, fielded questions and got approval from different ethics committees consisting of experts from different areas (law, medicine, management, basic-science, human-rights and safety). These taught me perseverance and built confidence. I managed the project by liaising with my supervisory team, staff, hospitals (managements, laboratories, accounts, medical records divisions), safety & ethics committees, 15 obstetricians across 2 hospitals and lab equipment vendors and worked out every nitty-gritty to keep the study running. These experiences have enhanced my leadership-people-negotiation-skills. Managing work in India and the UK have taught me adaptability and multitasking. Identifying and convincing pregnant women to participate in my study, to share their personal details with socially-sensitive approaches, ensuring participant safety have enhanced my patience and empathy. I have gained knowledge in nutritional epidemiology aspects of GDM, acquired skills to organise data, analyse and critically interpret findings.

10.5. Conclusions

My study showed, consistent with many other studies, that higher body mass index is a strong risk factor for GDM. The study did not identify specific foods or diet patterns convincingly linked to GDM risk in this Indian population. A balanced, nutritious and diverse diet, as recommended by the current Indian dietary guidelines (figure 10.3), along with regular moderate physical activity, is important for women to achieve a healthy pre-pregnant BMI and avoid excess adiposity. However, I am unable to make any additional specific dietary recommendations based on my data. I found that low serum ferritin levels in early pregnancy were associated with a lower risk of GDM

compared to normal ferritin levels. Moreover, women taking iron supplements in early pregnancy had a higher risk of GDM, although because women are generally prescribed a combination of iron and calcium+vitamin D, it was impossible to separate the associations of these two supplements. Together these findings add to evidence from several other studies linking higher iron status and/or use of iron supplements to an increased risk of GDM. However, understanding the role of iron in the aetiology of GDM requires further research.

10.6. Future directions

In the future, I plan to analyse quantified dietary data as predictors of GDM. Using frequency of intake enables us to compare findings with studies done elsewhere in the world. However, there may be variation within similar frequency of intake due to different portion sizes. I plan to develop diet indices applicable to reproductive-aged women in India; and also examine whether cultural beliefs are related to dietary exposures. Identifying barriers to improve women's diets may be useful for future intervention studies. Continuous blood glucose values as an outcome may give information on women who were on the borderline of developing GDM.

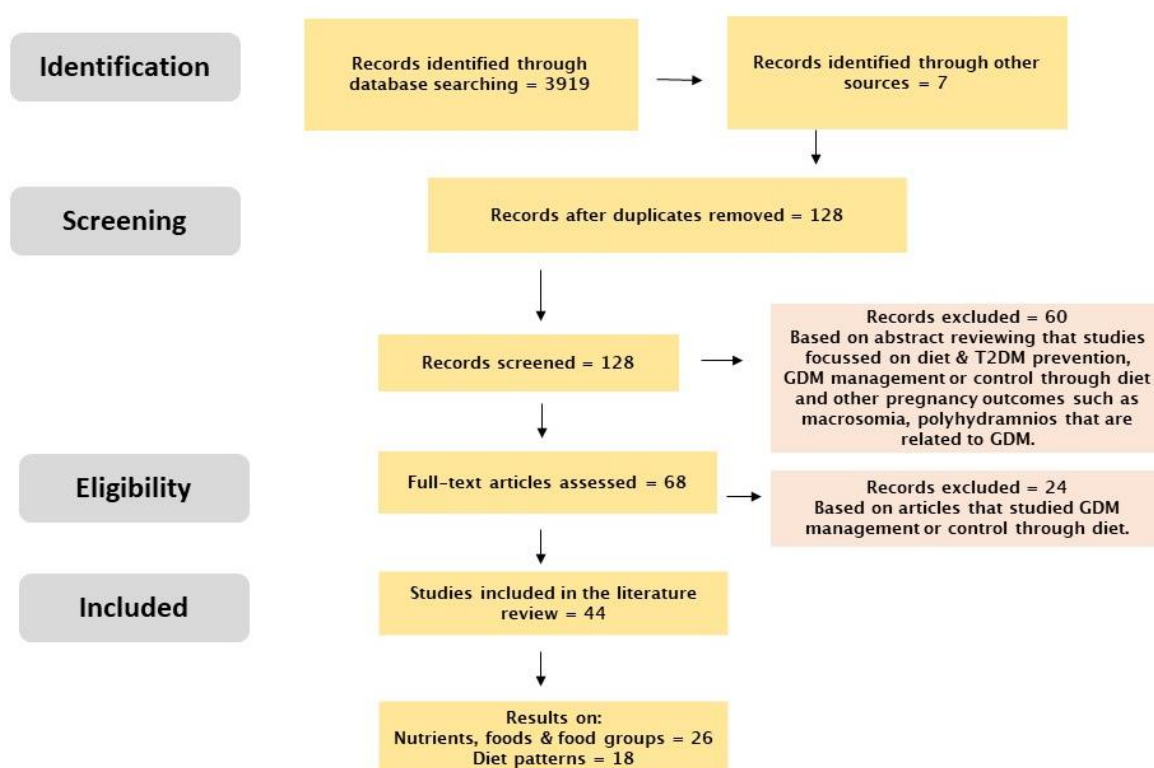
APPENDICES

APPENDIX A

DIET AND GDM LITERATURE SEARCH

A systematic literature search was conducted with the research question, 'Is there evidence linking diet before/ during pregnancy (as foods, food groups nutrients from food intake and diet patterns) to the risk of developing GDM?' The process (figure A) is described below:

Figure A: Literature search strategy process (format from Preferred Reporting Items for Systematic Reviews and Meta-Analyses, PRISMA, 2009)



Population: Reproductive-aged and pregnant women

Key words, synonyms & medical subject headings used:

Exposure: “primary prevention”, “diet”, “dietary”, “diet factors”, “nutrients”, “nutrition”, “nutritional factors”, “foods” and “food groups”. “pre-conception diet”, “peri-conception diet”, “before pregnancy diet”, “pregnancy diet”, “diet pattern”, “dietary pattern”.

Outcome: “gestational diabetes”, “gestational diabetes mellitus”, “pregnancy diabetes”, “diabetes in pregnancy”.

Research time frame: 1948 - 2019

Databases used: Pubmed, Embase, Cochrane, Web of Science and Google Scholar.

Inclusion criteria: Study search was broad in nature due to heterogeneity across studies in dietary factors, GDM diagnostic criteria, confounding factors used in analysis, effect estimates, and study design and few studies in Lower and Middle Income countries.

- i) Search was restricted to English and human populations and observational studies (prospective cohort, cross sectional & case-control studies).
- ii) Exposure was diet before and during pregnancy and outcome was development of GDM.
- iii) The literature search was broad in order to collect evidence on all aspects of an overall diet. Studies that investigated dietary exposures in terms of foods, food groups, diet patterns and indices were selected. Studies with nutrient-approach were included where nutrients of food-intakes were studied.
- iv) Studies that had focussed on GDM primary prevention were selected. Therefore, women with all ages, with low and high risk factors of GDM, and a range of body weights and BMI will be included. Studies that had focussed on GDM prevention were selected. Studies using GDM as an outcome from various screening methods such as NDDG, ADA, WHO, Carpenter & Coustan and IADPSG were used.
- v) Studies with all sample sizes were included. This was decided based on the fact that only Nurses' Health study had a very large sample size of >13,000. Rest all had smaller samples than this, and any arbitrary cut-off of sample size was not meaningful. Studies with smaller sample also added value, if they had clear objectives and met other inclusion/ exclusion criteria.
- vi) Studies which used dietary assessment methods such as food frequency questionnaire (FFQ), weighed records and 24-hour recalls were included.
- vii) Studies that adjusted for confounders such as age, T2DM family history, BMI etc. were included. However, no specific list of confounders was applied as this was heterogeneous across studies.

Exclusion criteria: My search did not include dietary components that are not 'normal foods' – for example, literature on probiotic consumption and GDM was not reviewed. Studies that investigated dietary management of GDM and pre-GDM were excluded. Studies that were done in women with history of GDM that focussed on secondary prevention were excluded. The reason for this was to choose a rationale applicable to my study design, which was study of peri-conception diet. Dietary management of GDM involves a much stricter approach of calories, food and restricts gestational weight gain. Studies that focus on Diet & T2DM prevention / GDM management / control through diet and assessed other pregnancy outcomes such as macrosomia or polyhydramnios but not GDM were excluded.

Data extraction: The following information was extracted from each included article: author, publication year, study name, design, sample size and number of GDM cases identified, country of study, dietary assessment method (number of items in the FFQ and information of whether the tool was validated), timing of dietary assessment method (before, during pregnancy including early, late etc.), GDM diagnosis criteria and timing, diet factors analysed, confounders adjusted for and results including statistics RR / OR and 95% CI and p-trend).

APPENDIX B

FORM 1: STUDY INCLUSION SCREENING LIST

Date of Interview: D M Y

Participant ID:

Study Participant Name:

Interviewer code

1. Is your Gestational age less than 16 weeks? (Yes = 1, No=0, don't know=99)

2. Are you carrying a single baby? (Yes = 1, No = 0, don't know = 99)

3. Are you planning to stay in Bengaluru throughout pregnancy? (Yes = 1, No = 0, don't know=99)

(If Yes = 1 move to question 5, If No = 0, move to question 4, If Don't know =99 move to question 4).

4. Are you planning to stay in Bengaluru till 24 weeks?

(Yes = 1, No =0, don't know=99)

(If the answer to this question is no and/ don't know=9, then the woman is not eligible for recruitment)

5. Are you planning to deliver in Bengaluru in this hospital? (Yes = 1, No=0, don't know=99) (If the answer to this question is No = 0 or don't know=9, then the woman is eligible for study but ensure to take the address and contact for the delivery period and inform that we will contact her in the future for baby details)

6. Have you ever been told/ diagnosed by a doctor as having diabetes or taking medication for it?

(Yes = 1, No=0)

Appendix B

7. Have you ever been diagnosed by a doctor to have diabetes only during pregnancy?

(Yes = 1, No=0) ☐

8. Are you willing to take part in the study? (Yes = 1, No = 0) ☐

9. Scan information from patient records	
Date	D M Y
Estimated gestational age @ recruitment	weeks days

Notes:

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APPENDIX C

FORM 2: STUDY PARTICIPANT INFORMATION SHEET

Gestational Diabetes Mellitus (GDM) is diabetes / high blood sugar which occurs for the first time during pregnancy. It is increasing in India and the latest research shows that about 20% of pregnancies may be affected by GDM. We are doing research into GDM because we know it can lead to difficulties for the mother and baby, and it's important for us to understand the causes of GDM, so that we can prevent it in the future. In the mother, GDM makes her feel unwell during pregnancy, sometimes needing tablets and/or injections, and can make the baby grow too big, requiring Caesarean delivery. The babies are at risk of developing a low blood sugar in the hours and days after delivery.

Research in western countries has suggested that a woman's everyday diet before she becomes pregnant can influence whether or not she develops GDM, but the evidence is not very clear, and we have no information at all for India

The knowledge from this project will be useful to understand the dietary and related risk factors for GDM in India and manage the growing GDM and type 2 diabetes burden in India.

PURPOSE OF THE STUDY: We plan to look at pregnant women's lifestyle factors such as food intake and physical activity to see whether they are related to increasing rates of GDM in Indian cities. This important topic has not been studied in detail in India before. It will address the research question: 'Are there specific dietary, lifestyle characteristics and blood vitamin levels which increase or decrease the risk of Gestational Diabetes in urban Indian women?' The ultimate aim will be to find out what women should ideally eat, or avoid, in the lead-up to pregnancy.

PROCEDURE: We will screen for healthy pregnant women who do not have diabetes, less than 16 weeks pregnant, carrying a single baby and who are planning to stay in Bangalore throughout their pregnancy. If you fit these criteria, we will explain the study to you and ask if you would like to participate. Only after you completely understand what it would involve being part of the study will we ask you to sign the consent form and recruit you for the study. Participation is entirely voluntary, and although we will get the best information if you stay in the study until the birth of your baby, you have the right to withdraw from the study at any time.

FIRST ROUND: In the first round you will be asked to give details on:

GENERAL HEALTH: We will collect your basic details, from you and your antenatal records, including your hospital number, phone number, home address, date of birth, previous pregnancies, whether you conceived normally or with medical assistance, your last menstrual period date and how many weeks pregnant you are, whether you used the oral contraceptive pill, family history of diabetes mellitus, medical history, and any medications, tablets and nutrition supplements you are taking.

Food, health and lifestyle details: Here, we will ask you to recall your food intake pattern in the month before you knew you were pregnant (using a special food frequency

questionnaire). We will ask you about your cultural beliefs about diet in pregnancy, and about your physical activity, using questionnaires.

SOCIO-ECONOMIC DETAILS: We will ask for details on your and your husband's education level, occupation and whether you own certain household commodities.

ANTHROPOMETRY: Your body weight and height will be recorded.

BLOOD BIOCHEMISTRY: You will be asked to give a 10 ml blood sample for Blood Sugar, Haemoglobin and certain vitamin levels (Folate, B12, ferritin and Vitamin D levels) in the blood. Some of these samples will be analysed immediately in the laboratory, others will be stored and analysed at the end of the study. No samples will be kept beyond the duration of this research study.

SECOND ROUND: In the second round you will be asked to give details on:

BLOOD BIOCHEMISTRY: You will be asked to have an Oral Glucose Tolerance Test, which is a standard test to screen women for gestational diabetes where you will be asked to give a 10 ml blood in total. It involves having one fasting blood sample, and two further blood samples 1 and 2 hours after consuming a drink containing 75 g glucose dissolved in water.

THIRD ROUND: We will collect: delivery details and baby details through you or your medical records, including the baby's date of birth, gender, mode of delivery, your total weight gain during pregnancy, and the baby's birth weight, length, head circumference, and placental weight if available.

RISKS AND DISCOMFORTS: The tests will take some of your time. The first round questionnaires and blood sample will take approximately 45 minutes, and we will make every effort to fit this in while you are waiting for your clinic consultation. The second round tests take approximately 2 hours, but this is part of the routine assessment at this stage of pregnancy. The third round will take approximately 10 minutes mainly collecting details from your medical records. Any blood sample involves a small amount of discomfort, and occasionally leaves a small bruise, though we will take every care to prevent this.

PARTICIPANT FEEDBACK:

You will be given the following:

- A 'Good Nutrition During Pregnancy' guide for all the 3 trimesters
- Your blood haemoglobin level in early pregnancy (a test for anemia)
- A Random Blood Glucose value, to screen for diabetes in early pregnancy
- Values from an Oral Glucose Tolerance Test (OGTT) in late pregnancy, to screen for Gestational Diabetes, with a report covering: fasting blood glucose, 1-hour post prandial blood glucose and 2-hour postprandial blood glucose.
- A 'Good Nutrition during Breastfeeding' guide.

All these pregnancy tips can be useful to monitor and promote good eating habits throughout pregnancy, important for the growth and birth of a healthy baby. The blood glucose and Haemoglobin tests will tell us if you have diabetes or anaemia, which could lead to timely interventions for a safe pregnancy. We will ensure that your haemoglobin, random blood glucose and glucose tolerance test results are conveyed to you personally and to your obstetrician. The micronutrient results (vitamin levels) will be measured only at the end of the study, for research purposes only, and so these will not influence your

pregnancy care. However, when we carry out these measurements, and if we find any signs of a vitamin deficiency, we will contact you. When the study is complete, we will send you a summary of our results and conclusions, and you will have an opportunity to discuss these with us.

CONFIDENTIALITY

All the information that we collect from you or from your records will be stored safely so that it is available only to authorized members of the research team, and to your chosen obstetric team. Paper questionnaires will be kept locked away, and data entered onto computers will be protected with passwords. In addition, when we analyse the data for the project, it will be anonymized, meaning that we will remove details such as your name, address and contact numbers, so you cannot be identified individually. Your name or individual information will not be referred to in publications of the results from this study.

THANK YOU FOR YOUR TIME.

PARTICIPANT CONSENT FORM

I consent to participate in this study. I consent to the study investigator and her authorized team members accessing my medical records to obtain the information listed in the information sheet, and using my data for the scientific purposes of the study. I understand that some of my blood sample will be stored for laboratory analyses, but that no samples will be stored once this project is completed.

I consent to the study investigator and her authorized team members accessing my medical records to obtain the information listed in the information sheet, and using my data for the scientific purposes of the study. I understand that some of my blood sample will be stored for laboratory analyses, but that no samples will be stored once this project is completed.

The investigator assures me that any data or questionnaires that carry my name will be stored safely and securely, will be accessible only to authorized members of her team, and will be treated confidentially. The set of data that is used for the main analysis of the study will be anonymized (my name will be removed). It is possible in future that other research teams will use some or all of the data to answer new scientific questions; this will happen only after proper checks as to their research credentials and only with the investigator's permission. In these circumstances the data will always be anonymized.

I understand that the record of this research becomes part of the MRC LEU U.K and Holdsworth Memorial Hospital's record and is protected as a confidential document. I understand that this record will only be available to investigators involved with this study.

Date:

Signature: ----- **Witness:** -----

THANK YOU FOR YOUR TIME AND PARTICIPATION

APPENDIX D

FORM 3: GENERAL DETAILS QUESTIONNAIRE

Date of Interview D M Y

Participant ID:

Participant Name

Interviewer code:

***From 1 – 19, ask all questions to the patient directly, 20 - note from records**

1. Consulting Obstetrician: Dr.

2. Participant's email id:

3. Participant's mobile number:

4. Participant's landline number:

5. Participant's current home address:

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.....

..... Bangalore

6. What is the participant's date of birth?

7. If Date of birth is not known: Age: years

8. What is the participant's Obstetric history (Indicate the number)?

How many times have you been pregnant?
*including current

How many times have you delivered?	
How many times have you had an abortion? (The term abortion indicates that it is natural or spontaneous loss of pregnancy and does NOT include medical termination of pregnancy)	

9. What is the current pregnancy's conception type (Yes = 1, No = 0)?

Natural ☐

Intra uterine Insemination (IUI) ☐

Intra Cytoplasmic Sperm Injection (ICSI) ☐

In Vitro Fertilization (IVF) ☐

10. Have you been on an oral contraception in the last year? Yes=1, No = 0 ☐

11. If yes, when did you stop taking it? D M Y

12. What is the participant's gestational age at recruitment: Weeks?

13. Have any of your immediate family members ever been told by a doctor that they have Diabetes mellitus? (Yes = 1, No = 0, don't know 9):

Mother	
Father	
Siblings	
Any Grandparent	

14. Have you had any serious illness in the past requiring hospital admission or medications for a prolonged period? (Yes = 1, No = 0, don't know 99):

If yes, Specify:

15. Do you have any current illness requiring hospital admission or medications for a prolonged period? (Yes = 1, No = 0, don't know 99):

If yes, Specify:

16. Have you ever been diagnosed by a doctor with Poly Cystic Ovarian Syndrome?

(Yes = 1, No = 0, don't know 99)

17. Have you ever been diagnosed by a doctor with thyroid trouble?

(Yes = 1, No = 0, don't know 99)

18. Are you taking folate supplementation (Yes = 1, No = 0, don't know 99)

19. How long have you been on folate supplementation? weeks

20. What is the dosage you have been taking? mg.

21. ANTHROPOMETRY: Recall and record measurements:

Pre – pregnancy weight		Kg.
Least body weight as an adult (>18 years)		Kg.

*Note from patient records for 21 – 25

22. Hospital MRN number:

23. What is the participant's Last Menstrual Period's date (LMP)?

24. Has your Obstetrician / Physician prescribed any medicines?

*Please copy medicine names directly from prescriptions.

25. What are the nutritional/ wellness supplements that you are taking currently?

Brand Name	Dosage	Daily Frequency	Has this been prescribed by your doctor? If Yes = 1 If No = 0	If self-prescribed, Please write why are they taking it? e.g.: Internet/ Relatives etc.

***Please copy medicine names directly from prescriptions.**

26. Record actual measurements:

Height		cm.
Current weight		Kg.

Notes:

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APPENDIX E

FORM 4: 24-HOUR RECALL QUESTIONNAIRE

Date of Interview D M Y

Study Participant ID number:

Study Participant Name:

Interviewer code Day : (Tick the day of interview recorded)

Monday ☐

Friday ☐

Tuesday ☐

Saturday ☐

Wednesday ☐

Sunday ☐

Thursday ☐

SECTION A:

Note: Please Record **ALL** food and drink consumed in the last 24 hours.

Ensure that you ask about drinks, fruit and any other snacks consumed

B1 = Small bowl, B2 = Medium bowl, B3 = Large bowl, B4 = Extra-large bowl	<u>C = CIRCUMFERENCE (1- 3)</u> C1 = small C2 = medium C3 = large
G1 = Small glass, G2 = Medium glass, G3 = Large glass	S = Small, M = Medium, L = Large
M2 = large mug	Pc1 = Chicken fry; Paneer Tikka Pc2 = Fish Fry Pc3 = Fish cutlet = Lamb, Beef, Pork cutlet
PL1 = small plate,	Cu 1 = Cucumber 1

	Cu 2 = Cucumber 2 Cu 3 = Cucumber 3
S1 = small sambhar spoon, S2 = medium sambhar spoon	
TS2 = medium teaspoon, TS3 = large teaspoon, TS4 = extra-large teaspoon	<u>THICKNESS:</u> T1 = THIN T2 = THICK
O2 = medium ghee / oil spoon	
<u>NUMBER OF UNITS</u> Please enter whole numbers or decimals in this box (e.g. 0.5, 0.25). NOT fractions (e.g. 1/2, 1/4)	

Time of day	Food Item Description	Unit of Measure	No of units	Size	Thick-ness
After getting up					
Breakfast					
Between Breakfast & Lunch					

Appendix E

Lunch					

Time of day	Food Item Description	Unit of Measure	No of units	Size	Thick-ness
Between Lunch & Dinner					
Dinner					
Bedtime					

APPENDIX F

FORM 5: FOOD FREQUENCY QUESTIONNAIRE

Date of recording D M Y

Study Participant ID number:

Study Participant Name:

 Interviewer code

TIME PERIOD:

The FFQ should be filled for the woman's dietary pattern during the month before she knew she was pregnant. Ask the woman to think back to what she was eating during the month before she knew she was pregnant.

FREQUENCY

D1 = Once daily, D2 = Twice daily, D3 = 3 Times daily etc.

W1 = Once weekly, W2 = Twice weekly, W3 = 3 times weekly, W4 = 4 times weekly etc.

M1 = Once monthly, M2 = Twice monthly, M3 = 3 times monthly

B1 = Small bowl, B2 = Medium bowl, B3 = Large bowl, B4 = Extra-large bowl	<u>C = CIRCUMFERENCE (1- 3)</u> C1 = small C2 = medium C3 = large
G1 = Small glass, G2 = Medium glass, G3 = Large glass	S = Small, M = Medium, L = Large
M2 = large mug	Pc1 = Chicken fry; Paneer Tikka Pc2 = Fish Fry Pc3 = Fish cutlet = Lamb, Beef, Pork cutlet
PL1 = small plate,	Cu 1 = Cucumber 1 Cu 2 = Cucumber 2 Cu 3 = Cucumber 3
S1 = small sambhar spoon, S2 = medium sambhar spoon	
TS2 = medium teaspoon, TS3 = large teaspoon, TS4 = extra-large teaspoon	<u>THICKNESS:</u> T1 = THIN T2 = THICK
O2 = medium ghee / oil spoon	
<u>NUMBER OF UNITS</u> Please enter whole numbers or decimals in this box (e.g. 0.5, 0.25). NOT fractions (e.g. 1/2, 1/4)	

Circle the appropriate measure

DON'T WRITE IN GREY SHADED AREA

	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
A. BEVERAGES						
1.	TEA		M2			
2.	COFFEE		M2			
3.	NORMAL COW'S MILK (AS PLAIN MILK / HORLICKS ETC.)		G3			
4.	SKIMMED COW'S MILK (AS PLAIN MILK / HORLICKS ETC.)		G3			
5.	BUTTERMILK		G3			
6.	HORLICKS, COMPLAN, BOOST, BOURNVITA		TS4			
7.	PRO PL		TS4			
8.	BABY AND ME		TS4			
9.	PRISTINE BALANCE PL		TS4			
10.	NUTRI RIGHT MOM		TS4			
11.	GRD SMART		TS4			
12.	GLUCON D POWDER		TS3			
13.	HERSHEYS SYRUP / CHOCO SYRUP		TS3			
14.	BADAM MILK		G3			
15.	ELECTORAL		G3			

	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
16.	TENDER COCONUT WATER		G3			
17.	SUGARCANE JUICE		G3			
18.	PACKAGED FRUIT JUICE (REAL, TROPICANA ETC.)		G3			
19.	FRESH VEGETABLE SOUPS		B4			
20.	FRESH NON – VEG SOUPS		B4			
21.	READY TO MAKE SOUPS		B4			
22.	COKE/ PEPSI / SPRITE / MIRINDA / FANTA OR OTHER FIZZY DRINK		G3			
23.	FROOTI / MAAZA / SLICE / NIMBOOZ / APPY FIZZ		G3			
24.	SQUASHES / SYRUPS (TANG/KISAN/ RASNA/ ROOHAFZA/LEMO NADE)		G3			
25.	FRESH FRUIT JUICE <i>SPECIFY FRUIT:</i>		G3			
26.	MILKSHAKES		G3			
27.	OTHER BEVERAGE 1, <i>*SPECIFY:</i>		G3			
SECTION B: FRUIT						
28.	APPLE		QUANTITY		S	

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	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
					M L	
29.	BANANA (PACCHE/ ROBUSTA/NENDRA KERALA TYPE)		QUANTITY			
30.	BANANA (YELAKKI)		QUANTITY			
31.	SWEET LIME		QUANTITY			
32.	GUAVA		QUANTITY		S M L	
33.	POMEGRANATE		B3			
34.	SAPOTA		QUANTITY			
35.	GRAPES (GREEN)		QUANTITY (NUMBER)			
36.	MUSK MELON		B3			
37.	PEAR		QUANTITY		S M L	
38.	PAPAYA		B3			
39.	PINEAPPLE		B3			
40.	MIXED FRUIT SALAD		B3			
41.	OTHER 1 SPECIFY: *				S M L	
SECTION C: DRIED FRUIT / NUTS						
42.	DATES		QUANTITY (NUMBER)			
43.	RAISINS		QUANTITY			
44.	FIGS		QUANTITY			
45.	PRUNES		QUANTITY			
46.	CASHEW NUT		QUANTITY			

	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
47.	ALMOND		QUANTITY			
48.	PISTACHIOS		QUANTITY			
49.	APRICOTS		QUANTITY			
50.	SUNFLOWER SEEDS		PS1			
51.	PUMPKIN SEEDS		PS1			
52.	FLAX SEEDS		PS1			
53.	GROUNDNUTS		PS1			
54.	OTHER 1, SPECIFY: *probe for walnuts					
SECTION D: RICE FOODS (Please read out all foods first before writing down frequency and amount: 55 - 62)						
55.	PLAIN/BOILED RICE		B3			
56.	RED RICE		B3			
57.	BROWN RICE		B3			
58.	RICE WITH DAL / SAMBHAR		B3			
59.	RICE WITH GLV SPECIFY GLV:		B3			
60.	COLOUR / SEASONED RICE (TAMARIND / LEMON / GHEE / TOMATO)		B3			
61.						

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	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
	VEGETABLE BATH / BISI BELE BATH / VEG KHICHDI		B3			
62.	CURD RICE		B3			
63.	RICE VERMICELLI / AVALAKKI/ PUFFED RICE (MANDAKKI)		B3			
64.	IDLY		QUANTITY		S L	
65.	PLAIN DOSA		QUANTITY		C	T1 T2
66.	MASALA DOSA		QUANTITY		C	T1 T2
67.	RICE ROTI		QUANTITY		C	T1 T2
68.	RICE PUTTU/KADABU		B3			
69.	OTHER 1, SPECIFY:					
70.	CHAPATHI		QUANTITY		C	T1 T2
71.	POORI		QUANTITY			
72.	PARANTHA		QUANTITY		C	T1 T2
73.	SWEET BUN / KARA BUN		QUANTITY			
74.	SLICED WHITE BREAD		SLICE			
75.	SLICED BROWN BREAD		SLICE			
76.	OTHER BREADS SPECIFY:		SLICE			
77.	UPPUMA		B3			
78.	BROKEN WHEAT / DALIA		B3			
79.	WHEAT FLAKES		B4			

	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
80.	PASTA / MACARONI		B3			
81.	SPAGETTI / NOODLES		B3			
82.	OTHER 1, SPECIFY:		B3			
SECTION E: RAGI FOODS						
83.	RAGI ROTI		QUANTITY		C	T1 T2
84.	RAGI BALL		B2			
85.	RAGI DOSA		QUANTITY		C	T1 T2
86.	RAGI MALT / MULTIGRAIN MALT / GANJI		G3			
87.	RAGI VERMICELLI		B3			
SECTION F: READY TO EAT BREAKFAST CEREALS						
88.	OAT + MILK		B4			
89.	OATS + WATER		B4			
90.	MUESLI		B4			
91.	ALL BRAN FLAKES		B4			
92.	CORN FLAKES (PLAIN)		B4			
93.	CORN FLAKES (WITH DRYFRUIT)		B4			
94.	CHIA SEEDS		PS1			
95.	OTHER 1, SPECIFY:					

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	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
96.	URAD VADA		QUANTITY			
97.	CHILAS / ADAI / PESARATTU		QUANTITY			
SECTION G: SIDE PREPARATIONS						
98.	LEGUME BASED DHAL (GREEN GRAM / BENGAL GRAM/ CHANNA/ RAJMA)		PS2			
99.	SPLIT DAL BASED DHAL (MOONG/ TOOR/ MASOOR)		PS2			
100.	POTATO PALYA		PS2			
101.	CARROT PALYA		PS2			
102.	MIX VEG SAMBHAR		S2			
103.	GLV / SOPPU SAMBHAR		S2			
104.	BEETROOT, RADISH, YAM, TAPIOCA PALYA		PS2			
105.	LADYSFINGER PALYA		PS2			
106.	CABBAGE / KNOL KHOL PALYA		PS2			
107.	CAULIFLOWER PALYA		PS2			
108.	CHOW CHOW, PUMPKIN, GOURDS		PS2			
109.	CAPSICUM PALYA		PS2			
110.	DRUMSTICK PALYA		PIECES			
111.	BRINJAL PALYA		PS2			

	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
112.	BEANS PLAYA		PS2			
113.	MUSHROOM PALYA		PS2			
114.	GLV / SOPPU PALYA SPECIFY GLV CODE:		PS2			
115.	MULTI VEGETABLE SAAGU		S2			
116.	RASAM		S2			
117.	OTHER 1, SPECIFY					
SECTION H: RAW VEGETABLES						
118.	CUCUMBER (without skin)				Cu 1 Cu 2 Cu 3	
119.	TOMATO		QUANTITY			
120.	ONION		QUANTITY			
121.	CARROT		QUANTITY			
122.	RADISH		QUANTITY			
123.	KOSAMBARI		B1			
124.	RUNNER BEANS		QUANTITY			
125.	OTHER 1, SPECIFY:					
SECTION I: PREPARATION (NON VEGETARIAN)						
126.	CHICKEN BIRIYANI		B3			

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	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
127.	CHICKEN FRY (ROASTED/GRILLED)		Pc1			
128.	CHICKEN CURRY		B2			
129.	FISH FRY		Pc2			
130.	FISH CURRY		S2			
131.	FISH CUTLET		Pc3			
132.	DRIED FISH / DRIED SEAFOOD		PS2			
133.	PRAWN, CRAB, SHELLFISH		PS2			
134.	LAMB, BEEF, PORK- FRY		PS2			
135.	LAMB, BEEF, PORK CUTLET		Pc3			
136.	LAMB, BEEF, PORK CURRY		B2			
137.	LIVER, BRAIN, KIDNEY		PS2			
138.	KEEMA CURRY		PS2			
139.	HAM / SALAMI / BACON		SLICE			
140.	MUTTON BIRIYANI		B3			
141.	EGG BIRIYANI		B3			
142.	EGG - BOILED (WITH YOLK)		QUANTITY			
143.	EGG - BOILED (WITHOUT YOLK)		QUANTITY			

	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
144.	EGG BURCHI, CURRY		PS2			
145.	OMELETTE WITH YOLK		QUANTITY			
146.	OMELETTE WITHOUT YOLK		QUANTITY			
147.	OTHER 1, *SPECIFY:					
148.	OTHER 2, *SPECIFY:					
SECTION J: JAM / CHUTNEY						
149.	PICKLE (LEMON / MANGO)		TS3			
150.	COCONUT CHUTNEY		PS1			
151.	GROUNDNUT CHUTNEY		PS1			
152.	KETCHUP		TS3			
153.	JAM		TS3			
154.	HONEY		TS3			
155.	OTHER 1, *SPECIFY:		TS3			
SECTION K: ADDED SUGAR						
156.	SUGAR IN FRUIT JUICE		TS2			
157.	SUGAR IN TEA		TS2			
158.	SUGAR IN COFFEE		TS2			

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	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
159.	SUGAR IN MILK		TS2			
160.	JAGGERY		TS2			

	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
SECTION L: SAVOURY (SALTED) SNACKS						
161.	PAPAD/ SANDIGE (HOME FRIED)		QUANTITY			
162.	NAMKEEN/MIXTURE S/ SAVOURIES		B3			
163.	CHAKLI/MURUKKU/ KODBALE		QUANTITY			
164.	PAKODA/ BONDA/ BHAJJI/ SAMOSA		QUANTITY			
165.	BABYCORN / GOBI MANCHURIAN		P1			
166.	BOILED / ROASTED CORN		B3			
167.	CHIPS (POTATO/PLANTAIN) FRENCH FRIES		B3			
168.	PUFF		QUANTITY			
169.	OTHER 1, SPECIFY:					
SECTION M: SWEET SNACKS						
170.	CHOCOLATE		QUANTITY		S M	

	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
	*SPECIFY BRAND:				L	
171.	TOFFEE/ CANDY		NUMBER			
172.	CAKE WITHOUT CREAM		QUANTITY			
173.	CAKE WITH CREAM / PASTRY		QUANTITY			
174.	SWEET BISCUITS (EG: PARLE G / GLUCOSE / TIGER / MARIE / GOODDAY)		QUANTITY			
175.	SALTED BISCUITS EG: MONACO / 50 – 50 / KRACKJACK / MASKA CHASKA		QUANTITY			
176.	CREAM BISCUITS EG: DREAM CREAM, MILKY BITE, JIM JAM, BOURBON, BRITANNIA PURE MAGIC		QUANTITY			
177.	KESARIBAATH / RAVA KESARI/ SHEERA/ SUJI HALWA		B2			
178.	OBBATTU/ HOLIGE / BOLI/ BOBATLU/ PURANPOLI		QUANTITY			
179.	BARFI /PEDHA		QUANTITY			
180.	GULAB JAMOON, JALEBI. JANGIR		QUANTITY			
181.	CHIKKI		QUANTITY			

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	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
182.	LADDOO, MYSORE PAK		QUANTITY			
183.	HALWA (DUMROOT/CARROT)		QUANTITY			
184.	KHEER / PAYASAM		B2			
185.	BENGALI SWEETS (RASGULLA / RASMALAI / CHUM CHUM / CHAMPAKALI/ MALAI SANDWICH)		QUANTITY			
186.	PUDDING/CUSTARD/S OUFFLE/CHEESE CAKE		B2			
187.	OTHER SWEETS OR SNACKS, *SPECIFY:					
SECTION N: FAST FOOD						
188.	CHATS MASALA PURI, PANI PURI, BHEL PURI			1		
189.	VEG PIZZA		SLICES		6'' (PERSONAL) 12'' (MEDIUM)	
190.	NON VEG PIZZA		SLICES		6'' (PERSONAL) 12'' (MEDIUM)	
191.	VEG BURGER		QUANTITY		SMALL LARGE	
192.	NON VEG BURGER		QUANTITY		SMALL LARGE	

	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICKNESS
193.	OTHER FAST FOOD, SPECIFY:					
SECTION O: MILK PRODUCTS						
194.	CURD		S1			
195.	RAITHA (ANY VEGETABLE RAITA)		S1			
196.	BUTTER		TS3			
197.	GHEE ON THE PLATE/ TABLE		O2			
198.	CHEESE AS: (GRATED CHEDDAR/MOZARELLA, SPREAD AND ALL TYPES)		PS1			
199.	PANEER CURRY (PANEER BUTTER MASALA/ KADAI PANEER)		B2			
200.	PANEER TIKKA		Pc1			
201.	ICECREAMS *include cup & stick icecreams			X 1		
202.	OTHERS SPECIFY: *					

SECTION P:

203. HOW MUCH OIL IS USED / PURCHASED FOR FOOD PREPARATION AND COOKING (PER MONTH? _____LITRES.

204. WHICH BRAND OF OIL DO YOU USE? _____

205. HOW MUCH GHEE IS PURCHASED FOR COOKING? _____ Kg.

206. HOW MANY COCONUTS ARE USED PER MONTH?

207. HOW MUCH DALDA DO YOU USE PER MONTH? _____ Kg.

208. WHICH BRAND OF SALT DO YOU BUY/ USE FOR COOKING? _____

209. HOW MANY SALT PACKETS (1 Kg) DO YOU PURCHASE PER MONTH? _____

210. HOW MANY PERSONS ARE THERE IN THE FAMILY? _____

SECTION Q (SEASONAL FOODS)**Do you consume any of these foods during the season?**

	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
211.	RAW MANGO		QUANTITY		S M L	
212.	RIPE MANGO		QUANTITY			
213.	JACKFRUIT		SEGMENT			
214.	AVRE KALU (PALYA / SAMBHAR / SNACKS / UPMA)		B3			
215.	ORANGE		QUANTITY			
216.	GREEN PEAS (PALYA / SAMBHAR / SNACKS / UPMA)		B3			
217.	GRAPES (PURPLE)		QUANTITY			
218.	WATERMELON		B3			
219.	LITCHI		QUANTITY			
220.	AMLA		QUANTITY			
221.	JAMUN		QUANTITY			

	ITEM	FREQUENCY	UNIT OF MEASURE	NO OF UNITS	SIZE	THICK-NESS
222.	PLUM		QUANTITY			
223.	CUSTARD APPLE		QUANTITY			
224.	STRAWBERRY		QUANTITY			

OTHERS * (PROBE LIST)

BEVERAGES: SOY MILK (G3), COCONUT MILK (G3)

FRUITS: KIWI (QUANTITY), AVOCADO (QUANTITY), ICE APPLE (QUANTITY)

SWEETS: BADUSHA (QUANTITY), KAJJAYA (QUANTITY), DOUGHNUTS (QUANTITY)

VEGETABLES: LETTUCE (B3), BROCCOLI (B3)

JAMS & JELLIES: PEANUT BUTTER(TS3), MAYONNAISE (TS3)

APPENDIX G

FORM 6: SOCIO ECONOMIC STATUS QUESTIONNAIRE

Date of Interview D M Y

Study Participant ID number:

Study Participant Name:

Interviewer code

Study Participant Religion:

A. What is your education level? (refer table 1)

B. What is your husband's education level? (refer table 1)

7	Professional degree, M.A, M.Sc., M.Com, M.Tech, MBBS, B.E, MSW, Postgraduate Diploma
6	B.A, B.Sc., B.Com, DME, DHMS, BPNA
5	HSC,ITI, Intermediate D.Ed., Post high-school diploma
4	High School certificate, S.SIC
3	Middle school completion
2	Primary school / literate
1	Illiterate

C. What is your occupation?

D. If currently not employed, what was your last paid occupation?

.....

E. What is the family's main breadwinner's occupation?

.....

F) What is the family's total monthly income? Rupees

Standard of Living Index

G) Family type:

1) Nuclear

2) Joint

3) Other

H) Number of persons (specify): _____

I) What is the main source of drinking water for members of your household?

1) Piped water

5) River/stream

2) Hand pump

6) Tanker

3) Well

7) Other (specify):

4) Public tap/p. hand pump/p. well

J) What kind of toilet facility does your household have?

1) Own flush toilet

2) Shared flush toilet

3) Public flush toilet

4) Own pit toilet/Latrine

5) Shared pit toilet/Latrine

6) Public pit toilet/Latrine

7) No facility/Bush/Field

8) Other

K) What is the main source of lighting for your household?

1) Electricity

2) Kerosene

3) Oil

4) Gas

5) Other (specify): _____

L) How many rooms are there in your household?

Rooms No: _____

M) Do you have a separate room that is used as a kitchen?

1) Yes

2) No

N) What type of fuel does your household mainly use for cooking?

1) Electricity

2) Wood

3) Crop residues

4) Liquid petroleum gas

5) Biogas

6) Coal/Charcoal/Coke

7) Kerosene

8) Other (specify): _____

O) Does this household own this house or any other house?

1) Yes

2) No

P) Type of house (record observation)

Roof _____

1) Pucca

Walls _____

2) Semi-pucca

Floor _____

3) Kachha

Q) Does this household own any agriculture land?

1) Yes (specify): _____ acres

2) No

R) Out of this how much is irrigated land?

1) _____ acres

2) None

S) Does this household own any livestock?

1) Yes (specify): _____ Number: _____

2) No

T) Does this household own any of the following? (NFHS 2)

1.	Mattress		(Yes = 1, N = 0, Don't know = 99)
2.	Pressure Cooker		(Yes = 1, N = 0, Don't know = 99)
3.	Chair		(Yes = 1, N = 0, Don't know = 99)
4.	Cot/Bed		(Yes = 1, N = 0, Don't know = 99)
5.	Table		(Yes = 1, N = 0, Don't know = 99)
6.	Clock/ Watch		(Yes = 1, N = 0, Don't know = 99)
7.	Electric fan		(Yes = 1, N = 0, Don't know = 99)
8.	Bicycle		(Yes = 1, N = 0, Don't know = 99)
9.	Radio/ Transistor		(Yes = 1, N = 0, Don't know = 99)
10.	Television (B &W)		(Yes = 1, N = 0, Don't know = 99)
11.	Television (Colour)		(Yes = 1, N = 0, Don't know = 99)
12.	Moped/Scooter/ Motorcycle		(Yes = 1, N = 0, Don't know = 99)
13.	Car/Jeep		(Yes = 1, N = 0, Don't know = 99)
14.	Water pump		(Yes = 1, N = 0, Don't know = 99)
15.	Bullock cart		(Yes = 1, N = 0, Don't know = 99)
16.	Thresher		(Yes = 1, N = 0, Don't know = 99)
17.	Tractor		(Yes = 1, N = 0, Don't know = 99)
18.	Refrigerator		(Yes = 1, N = 0, Don't know = 99)
19.	Telephone		(Yes = 1, N = 0, Don't know = 99)
20.	Sewing machine		(Yes = 1, N = 0, Don't know = 99)

ADDITIONAL HOUSEHOLD POSSESSIONS FROM NFHS 4

21.	Air conditioner		(Yes = 1, N = 0, Don't know = 99)
22.	Washing machine		(Yes = 1, N = 0, Don't know = 99)
23.	Mobile Telephone		(Yes = 1, N = 0, Don't know = 99)
24.	Computer		(Yes = 1, N = 0, Don't know = 99)

25.	Internet (broadband)		(Yes = 1, N = 0, Don't know = 99)

ADDITIONAL HOUSEHOLD POSSESSIONS NOT INCLUDED IN NFHS 2 or 4

26.	Television (Plasma screen)		(Yes = 1, N = 0, Don't know = 99)

APPENDIX H

FORM 7: PHYSICAL ACTIVITY QUESTIONNAIRE

Date of Interview D M Y

Study Participant ID number:

Study Participant Name:

Interviewer code

***Indicate 0 for not doing, 99 for don't know)**

1. During the last 7 days, on how many days did you do vigorous physical activity?

Days (Don't know/not sure = 99, refused = R)

(Vigorous activity: Activities which make the woman breathe harder than normal).

2. How much time did you usually spend doing vigorous physical activities on one of those days?

Hours/ day or mins/day

(Don't know/not sure = 9, refused = R)

3. During the last 7 days, on how many days did you do moderate physical activity?

Days (Don't know/not sure = 99, refused = R)

(Moderate activity: Activities which make the woman breathe a little harder than normal. E.g. Fast walking etc.)

4. How much time did you usually spend doing moderate physical activities on one of those days?

Hours / day or mins/day

(Don't know/not sure = 99, refused = R)

5. **During the last 7 days, on how many days did you walk for at least 10 minutes at a time?**

Days (Don't know/not sure = 99, refused = R)

6. **How much time did you usually spend walking on one of those days?**

Hours/ day or mins/day

(Don't know/not sure = 99, refused = R)

7. **During the last 7 days, how much time did you usually spend sitting on a week day?**

Hours/ day or mins/day

(Don't know/not sure = 99, refused = R)

8. **Additional question (not in IPAQ):**

On an average how much time do you spend in a day, viewing a screen (mobile and smart phone and touch pad and laptop and desktop and Television)?

Hours/ day or mins/day

Notes:

.....

.....

.....

.....

APPENDIX I

FORM 8: 12 – 16 WEEKS BLOOD SAMPLE PROFORMA

Date of Interview D M Y

Study Participant ID number:

Study Participant Name:

Interviewer code

1. Date of blood collection D M Y

2. Blood Collected (Yes = 1, No = 0)

If No, state reason:

.....

1. Blood collected for micronutrient analysis (For Yes = 1; No = 0)

Time of collection:

If No, state reason:

.....

2. Blood collected for Hb + RBS (For Yes = 1; No = 0)

3. Time of collection:

If No, state reason:

.....

4. Values of test results: Hemoglobin mg/dl

Random plasma glucose mg/dl

APPENDIX J

Form 9: 24 – 28 WEEKS OGTT FOLLOW UP PROFORMA

Date of Interview D M Y

Study Participant ID number:

Study Participant Name:

Interviewer code

3. Date of blood collection D M Y

4. Any food consumed in the last 8 hours? (For Yes = 1; No = 0; Don't know = 99)

5. Blood Collected for OGTT (For Yes = 1; No = 0)

If No, state reason:

.....

6. Blood collection time:

Fasting

1 - hour

2 - hour

7. Current weight Kg.

8. PRESCRIBED MEDICINES

NAME	DOSAGE	FREQUENCY IN A DAY	REASON

*Please copy medicine names directly from containers / prescription. If women do not have the medicine names with them, telephone later to obtain these.

WELLNESS/ NUTRITIONAL SUPPLEMENTS

BRAND NAME	DOSAGE	DAILY FREQUENCY

9. Test Result of 75 gram OGTT

Fasting plasma glucose mg/ dl

1 hour postprandial plasma glucose mg/dl

2 hour postprandial plasma glucose mg/dl

Treatment: Diet control only (Yes = 1, No = 0) ☐ Diet + Oral Hypoglycaemic agents

(Yes = 1, No = 0) ☐ **Specify:** _____

Insulin ☐ **Specify:** _____

Oral Hypoglycaemic agents + Insulin ☐ **Specify:** _____

Participant informed: ☐ **Obstetrician informed:** ☐

APPENDIX K

BANGLES FFQ ATLAS SAMPLE

1) TEA



2) COFFEE



3) NORMAL COW'S MILK



4) SKIMMED COW'S MILK



APPENDIX L

FOODS IN COMMON LANGUAGES MANUAL SAMPLE

A. BEVERAGES					
Sl No	English	Hindi	Kannada	Tamil	Telugu
1.	TEA	चाय	ಚಹಾ	Tēnīr	Ṭī
2.	COFFEE	काँफी	ಕಾಫಿ	Kāpi	Kāphī
3.	FRESH MILK (COW)	दूध	ಹಾಲು	Pāl	Pālu
4.	BUTTERMILK	लस्सी	ಮಜ್ಜಿಗೆ	Mōr	Majjiga
5.	PACKET MILK SKIMMED	पैकेटदूधस्किमड	ಕೆನೆ ತೆಗೆದ ಹಾಲು	Nirampiyāā ṭainīkkiyap āl	Vennatīsin apālu

APPENDIX M

FOOD GROUPING, I (21 FOOD GROUPS)

1. MILLED CEREALS & PRODUCTS	
55.	PLAIN/BOILED RICE
58.	RICE WITH DAL / SAMBHAR
59.	RICE WITH GLV SPECIFY GLV:
60.	COLOUR / SEASONED RICE (TAMARIND / LEMON / GHEE / TOMATO)
61.	VEGETABLE BATH / BISI BELE BATH / VEG KHICHDI
62.	CURD RICE
63.	RICE VERMICELLI / AVALAKKI/ PUFFED RICE (MANDAKKI)
64.	IDLY
65.	PLAIN DOSA
66.	MASALA DOSA
67.	RICE ROTI
68.	RICE PUTTU/KADABU
70.	CHAPATHI
71.	POORI
72.	PARANTHA
73.	SWEET BUN / KARA BUN
74.	SLICED WHITE BREAD
75.	SLICED BROWN BREAD
77.	UPPUMA
80.	PASTA / MACARONI
81.	SPAGETTI / NOODLES
92.	CORNFLAKES (PLAIN)
93.	CORN FLAKES (WITH DRYFRUIT)
2. WHOLE GRAIN CEREALS	
56.	RED RICE
57.	BROWN RICE
78.	BROKEN WHEAT / DALIA
79.	WHEAT FLAKES
83.	RAGI ROTI
84.	RAGI BALL
85.	RAGI DOSA
86.	RAGI MALT / MULTIGRAIN MALT / GANJI
87.	RAGI VERMICELLI
88.	OAT + MILK
89.	OAT + WATER

90.	MUESLI
91.	ALL BRAN FLAKES
94.	CHIA SEEDS
3. PULSE AND LENTIL PREPARATIONS	
97.	CHILAS/ ADAI/ PESARATTU
98.	LEGUME BASED DHAL (GREEN GRAM / BENGAL GRAM/ CHANNA/ RAJMA)
99.	SPLIT DAL BASED DHAL (MOONG/ TOOR/ MASOOR)
214.	AVRE KALU (PALYA / SAMBHAR / SNACKS / UPMA)
216.	GREEN PEAS (PALYA / SAMBHAR / SNACKS / UPMA)
4. SALADS & RAW VEGETABLES	
118.	CUCUMBER (without skin)
119.	TOMATO
120.	ONION
121.	CARROT
122.	RADISH
123.	KOSAMBARI
124.	RUNNER BEANS
125.	RAW GREENS
166.	BOILED / ROASTED CORN
5. COOKED VEGETABLES	
19.	FRESH VEGETABLE SOUPS
100.	POTATO PALYA
101.	CARROT PALYA
102.	MIX VEG SAMBHAR
104.	BEETROOT, RADISH, YAM, TAPIOCA PALYA
105.	LADYSFINGER PALYA
106.	CABBAGE / KNOL KHOL PALYA
107.	CAULIFLOWER PALYA
108.	CHOW CHOW, PUMPKIN, GOURDS
109.	CAPSICUM PALYA
111.	BRINJAL PALYA
112.	BEANS PLAYA
113.	MUSHROOM PALYA
115.	MULTI VEGETABLE SAAGU
116.	RASAM
166.	BOILED/ ROASTED SWEET CORN
6. POTATO PALYA	
100.	POTATO PALYA
7. POTATO CONTAINING DISHES	
66.	MASALA DOSA
72.	ALU PARANTHA
164.	ALU BONDA

8. COOKED GREEN LEAFY VEGETABLES	
103.	GLV / SOPPU SAMBHAR
110.	DRUMSTICK PALYA
114.	GLV / SOPPU PALYA <i>SPECIFY GLV CODE:</i>
9. FRESH FRUIT, DRIED FRUIT & FRUIT JUICES	
16.	TENDER COCONUT WATER
25.	FRESH FRUIT JUICE <i>SPECIFY FRUIT:</i>
28.	APPLE
29.	BANANA (PACCHE/ROBUSTA/ NENDRA – KERALA TYPE)
30.	BANANA (YELAKKI)
31.	SWEET LIME
32.	GUAVA
33.	POMEGRANATE
34.	SAPOTA
35.	GRAPES (GREEN)
36.	MUSK MELON
37.	PEAR
38.	PAPAYA
39.	PINEAPPLE
40.	MIXED FRUIT SALAD
41.	OTHER 1, <i>SPECIFY:</i> *
42.	DATES
43.	RAISINS
44.	FIGS
45.	PRUNES
49.	APRICOTS
211.	RAW MANGO
212.	RIPE MANGO
213.	JACKFRUIT
215.	ORANGE
217.	GRAPES (PURPLE)
218.	WATERMELON
219.	LITCHI
220.	AMLA
221.	JAMUN
222.	PLUM
223.	CUSTARD APPLE
224.	STRAWBERRY
10. NUTS & SEEDS	
46.	CASHEW NUT
47.	ALMOND
48.	PISTACHIOS

50.	SUNFLOWER SEEDS
51.	PUMPKIN SEEDS
52.	FLAX SEEDS
53.	GROUNDNUTS
54.	WALNUTS
150.	COCONUT CHUTNEY
151.	GROUNDNUT CHUTNEY
11. FISH & SEAFOOD	
129.	FISH FRY
130.	FISH CURRY
131.	FISH CUTLET
132.	DRIED FISH / DRIED SEAFOOD
133.	PRAWN, CRAB, SHELLFISH
12. EGG & EGG PREPARATIONS	
141.	EGG BIRIYANI
142.	EGG – BOILED (WITH YOLK)
143.	EGG – BOILED (WITHOUT YOLK)
144.	EGG BURCHI, CURRY
145.	OMELETTE WITH YOLK
146.	OMELETTE WITHOUT YOLK
13. POULTRY	
126.	CHICKEN BIRIYANI
127.	CHICKEN FRY(ROASTED/GRILLED)
128.	CHICKEN CURRY
14. MEAT	
20.	FRESH NON – VEG SOUPS
134.	LAMB, BEEF, PORK - FRY
135.	LAMB, BEEF, PORK - CUTLET
136.	LAMB, BEEF, PORK CURRY
137.	LIVER, BRAIN, KIDNEY
138.	KEEMA CURRY
139.	HAM / SALAMI / BACON
140.	MUTTON BIRIYANI
15. MILK AND DAIRY PRODUCTS	
1.	TEA
3.	NORMAL COW'S MILK (AS PLAIN MILK / HORLICKS ETC.)
4.	SKIMMED COW'S MILK (AS PLAIN MILK / HORLICKS ETC.)
5.	BUTTERMILK
14.	BADAM MILK
194.	CURD
195.	RAITHA (ANY VEGETABLE RAITA)
198.	CHEESE AS: (GRATED CHEDDAR/MOZARELLA, SPREAD AND ALL TYPES)

Appendix M

199.	PANEER CURRY (PANEER BUTTER MASALA/ KADAI PANEER)
200.	PANEER TIKKA
16. COFFEE	
17. FRIED & FAST FOOD	
96.	URAD VADA
161.	PAPAD/ SANDIGE (HOME FRIED)
162.	NAMKEEN/MIXTURES/ SAVOURIES
163.	CHAKLI/MURUKKU/KODBALE
164.	PAKODA/BONDA/BHAJJI/SAMOSA
165.	BABY CORN / GOBI MANCHURIAN
167.	CHIPS (POTATO/PLANTAIN) , FRENCH FRIES
168.	PUFF
188.	CHATS (MASALA PURI, PANI PURI, BHEL PURI)
189.	VEG PIZZA
190.	NON VEG PIZZA
191.	VEG BURGER
192.	NON VEG BURGER
196.	BUTTER
197.	GHEE ON THE PLATE/ TABLE
18. ADDED SUGAR, SSB & HIGH SUGAR PRODUCTS	
12.	GLUCON D POWDER
13.	HERSHEYS SYRUP / CHOCO SYRUP
15.	ELECTORAL
17.	SUGARCANE JUICE
18.	PACKAGED FRUIT JUICE (REAL, TROPICANA ETC.)
22.	COKE/ PEPSI / SPRITE / MIRINDA / FANTA OR OTHER FIZZY DRINK
23.	FROOTI / MAAZA / SLICE / NIMBOOZ / APPY FIZZ
24.	SQUASHES / SYRUPS (TANG/KISAN/ RASNA/ ROOHAFZA/LEMONADE)
153.	JAM
154.	HONEY
156.	SUGAR IN FRUIT JUICE
157.	SUGAR IN TEA
158.	SUGAR IN COFFEE
159.	SUGAR IN MILK
160.	JAGGERY
170.	CHOCOLATE *SPECIFY BRAND:
171.	TOFFEE/ CANDY
172.	CAKE WITHOUT CREAM
173.	CAKE WITH CREAM / PASTRY
174.	SWEET BISCUITS (EG: PARLE G / GLUCOSE / TIGER / MARIE / GOODDAY)
175.	SALTED BISCUITS (EG: MONACO / 50 – 50 / KRACKJACK / MASKA CHASKA

176.	CREAM BISCUITS EG: DREAM CREAM, MILKY BITE, JIM JAM, BOURBON, BRITANNIA PURE MAGIC
177.	KESARIBAATH / RAVA KESARI/ SHEERA/ SUJI HALWA
178.	OBBATTU/ HOLIGE / BOLI/ BOBATLU/ PURANPOLI
179.	BARFI /PEDHA
180.	GULAB JAMOON, JALEBI. JANGIR
181.	CHIKKI
182.	LADDOO, MYSORE PAK
183.	HALWA (DUMROOT/CARROT)
185.	BENGALI SWEETS – RASGULLA / RASMALAI / CHUM CHUM / CHAMPAKALI/ MALAI SANDWICH
186.	PUDDING/CUSTARD/SOUFFLE/CHEESE CAKE
19. NUTRIENT ENRICHED BEVERAGE SUPPLEMENTS	
6.	HORLICKS, COMPLAN, BOOST, BOURNVITA
7.	PRO PL
8.	BABY AND ME
9.	PRISTINE BALANCE PL
10.	NUTR IRIGHT MOM
11.	GRD SMART
20. HIGH SALT PRODUCTS	
21.	READY TO MAKE SOUPS
149.	PICKLE (LEMON/ MANGO)
152.	KETCHUP
155.	OTHER CHUTNEY POWDERS
175.	SALTED BISCUITS (EG. MONACO/ FIFTY FIFTY/ KRACKJACK/ MASKA CHASKA).
21. VISIBLE FAT	
196.	GHEE
197.	BUTTER

APPENDIX N

NUTRITION COUNSELLING PAMPHLET

RECIPES FOR PREGNANCY

Mixed vegetable soup

Ingredients

- Carrots : 25 gm
- French Beans : 25 gm
- Peas : 15 gm
- Tomato Puree : 25 gm
- Garlic/Garlic : 25,25gm
- Coriander leaves : 25 gm
- Water : 3 glasses
- Butter or Oil : 10 ml
- Salt and Pepper : 5 gm

Method

- Add Oil or butter in a vessel ... Fry ginger and garlic paste, add tomato puree, carrots, French beans, pea and water. Pressure cook for 5-6 minutes.
- Add coriander leaves., Boil for 2-3 minutes. Serve hot.



Shallow Fried Gobi Paratha

Ingredients

- Wheat Flour : 30g
- Grated Cauliflower : 50g
- Coriander leaves : 25g
- Green chilies : 25g
- Ginger : 25g
- Salt : 5gm
- Red chili powder : 5gm
- Garam Masala : 5g
- Ajwain : 2.5 gm
- Oil for frying : 25ml

Method

- Make dough with wheat flour. Knead the dough with the rest of the ingredients
- Make two medium size chapatti, add the filling to one chapatti and cover it with the second one. Now roll it slightly.
- Cook on a pre-heated flat griddle plate.
- Turn it and pour half tablespoon oil or butter. Cook on a low heat till golden brown.



GOOD NUTRITION DURING PREGNANCY

benefits 2 lifetimes !

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Bangalore Nutrition Gestational
diabetes LiFestyle Study

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WHY IS EATING A NUTRITIOUS DIET IMPORTANT IN PREGNANCY?

- Good nutrition in pregnancy is critical.
- There is no need to go on a special diet but it's important to eat a variety of different foods every day, to get the right balance of nutrients that you and your baby need.
- Right nutrition can help promote your baby's growth and development
- The food you eat is the main source of nourishment for your baby, so it's important to consume foods that are rich in nutrients.

A healthy diet helps:

- Optimal development of the baby and increased chances of having a baby with optimal birth weight (2.5 – 3.5 Kg).
- Mothers avoid pregnancy complications like anemia, high blood pressure and gestational diabetes.
- A good diet also reduces morning sickness, fatigue and constipation. Women who eat right during pregnancy and gain the right amount of weight are more likely to return to their pre-pregnancy weight sooner.

RECIPES FOR PREGNANCY

Rajgira chikki

Ingredients:

- 30 gm runda / rajgira / cholai
- 45 gm jaggery
- 2 cups water

Method:

- Roast the rajgira seeds until it starts to pop and then keep aside
- Place jaggery and water in a pan, and dissolve jaggery over low heat.
- When dissolved increase the heat and bring to a boil and cook over high heat till a 2-3 thread consistency is reached.
- Mix in the rajgira into the mixture.
- Transfer at once onto the greased surface, pat to level and leave to set.



Ragi Upma

Ingredients

- 1 cup ragi (nachni / red millet) flour
- 1/2 cup semolina (rava)
- 2 tsp oil
- 1 tsp mustard seeds (rai / sarson)
- a pinch of asafoetida (hing), salt
- 2 to 3 curry leaves (kadi patra)
- 2 1/2 tsp finely chopped green chillies
- 1/4 cup finely chopped onions, carrots
- 1/4 cup finely chopped coriander (dhania)

Method:

- Dry roast the ragi flour and semolina on medium flame for 5 minutes.
- Heat the oil in a pan and add the mustard seeds.
- When the seeds crackle, add the asafoetida, curry leaves, green chillies and onions and sauté for 1 minute. Add carrots,
- Add the roasted ragi- semolina mixture and salt and sauté for 1 to 2 minutes
- Add 4 cups of hot water and cook on a slow flame for 2 to 3 minutes
- Garnish with coriander



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OPTIMAL NUTRITION : RIGHT FOR YOU

Fats and Oils : 6 portion (5g each) and Sugar: 4 portions (5g each)

Cereals, Breads and Pasta : 9 portions (30g each)

A healthy diet consists of :

- Carbohydrates : Cereals, Bread and pasta
- Proteins : Dals and Meat
- Fats : Sugars and oils
- Vitamins & Minerals : Fruits, Vegetables and Dairy Products
- Plenty of Water

NUTRIENTS

ENERGY:
Your needs increase to meet the demands. To carry out activities without getting tired energy dense foods are to be consumed. During this stage an additional 350kcal are to be in the diet.

FAT:
It is a concentrated source of energy, that are essential for your baby's brain, eyes and nervous system. It also enhances taste of foods. About 30g is needed a day. Good oils like til, safflower, groundnut oil should be used. Avoid street fried foods like jilebi, samosa etc

CALCIUM:
Calcium for your baby is at your expense. It helps calcification of the baby's bones and teeth. About 1200mg is needed per day. Rich sources are bajra, wheat, Bengal gram, black gram, horse gram, rajmah, amaranth, colocasia, shepu, Lotus stem, til seeds, dates, fish and milk.

IRON:
Iron helps prevent anemia by helping in the production of hemoglobin. Foxtail millet, ragi, red meat, dried beans, spinach, dried fruits, wheat germ, oatmeal etc are iron rich.

VITAMIN:
Vitamin A,D,E,K,B & C are all important. Liver, milk, eggs, carrots, spinach, fish, rice, peanut, bananas etc meet major vitamins. Rich vitamin intake can increase energy levels, promote good eyesight and healthy skin, thus maintaining overall immunity, .

FIBRE
Fibre helps prevent constipation. It maintains a healthy gut and weight. About 30g of fibre is needed in a day. The rich sources are whole grain foods like brown rice, raw vegetables & fruits and green leafy vegetables.

WATER
It is a must to stay hydrated. Water helps prevent headaches, dizziness, constipation and keeps you energetic! Drink approx 10 glasses per day inclusive of water in juice. Suck on ice chips if frequently thirsty. Add sprig of Mint, elaichi, dhania, ginger, falooda seeds to enhance flavor of the water.

FOODS THAT HAVE NEGATIVE IMPACT ON HEALTH

- Cut coffee & tea completely. But if it is impossible then limit caffeine (1 mug of coffee / tea).
- Avoid swordfish, king mackerel, shark and sushi during pregnancy.
- Avoid leftover food refrigerated for more than 12 hours
- Avoid excess processed foods as they contain sodium and potassium benzoates and Mono Sodium Glutamate (MSG) .
- Avoid smoked fish & pickled foods as they contain high amount of nitrates.
- Avoid soft cheeses (brie, camembert) and it is better to consume hard cheeses like cheddar, mozzarella and cottage cheese.
- Avoid partially cooked & uncooked meat and chicken & Avoid raw and half cooked eggs and half boiled milk (as they can cause food borne infections like listeriosis and toxoplasmosis).

Food Safety for Moms-to-Be

Foodborne Illness Can Affect Your Baby!

CLEAN
Wash hands and surfaces often.

SEPARATE
Don't cross contaminate.

COOK
Cook to proper temperatures.

CHILL
Refrigerate promptly.

Practice good food safety
before, during and after
your pregnancy.

APPENDIX O

SAMPLE: CODING OF OTHER FOODS & MATCHING WITH EXISTING FOODS ON FFQ ITEMS ON BANGLES FFQ WITH RATIONALE

Other foods listed in the beverages section		
Food item on FFQ	Rationale of matching with the existing FFQ items	FFQ item name
Coconut milk	Closest is coconut chutney, mineral and vitamin composition different from cows milk	J150f
Green tea	Herbal drinks - new section	A1f
Lion dates syrup	Closest is dates	C42f
B-protein	Closest in nutritional composition to Pro PL	A7f
Badam vermicelli milk	Closest is payasam - milk, vermicelli and sugar	M184f
Sweetened lemon tea	Closest to high sugar sweetened beverages.	A24f
Protein powder	Similar in nutrient composition to Pro PL	A7f
Veg juice	Closest to veg soup	A19f
Hespros granules	Closest in nutritional composition to Pro PL	A7f
Carrot beetroot juice	Closest to veg soup	A19f
Barley water	Closest in nutritional composition to tender coconut water	A16f

APPENDIX P

CHAPTER 4: REGRESSION ANALYSIS TABLES OF POPULATION CHARACTERISTICS AS PREDICTORS OF WEEKLY FREQUENCY OF FOOD GROUP INTAKE

Table 4.1: Regression analysis of hospital as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups B = Baptist C = Cloudnine	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Hospital type Baptist (B) = 0, Cloudnine (C) = 1		
			β ¹ / Odd s ratio ^{2,3}	95% CI	p
Continuous variable, z-standardised; units = SD					
Milled cereals & products ¹	B = 38.2 (31.0, 46.0) C = 33.5 (27.3, 41.5)	785 (100.0)	-0.40	-0.59, 0.21	<0.001
Binary variable, 0 = none* & 1 = any					
Wholegrain cereals ²	B = 5.0 (0.7, 8.0) C = 2.5 (0.5, 7.5)	0 = 112 (14.3) 1 = 673 (85.7)	0.96	0.55, 1.65	0.87
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Pulse & lentil preparations ¹	B = 4.0 (2.2, 6.0) C = 7.3 (3.2, 10.1)	785 (100.0)	0.59	0.40, 0.78	<0.001
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Salads & raw vegetables ¹	B = 3.0 (1.2, 5.5) C = 3.7 (1.9, 8.8)	785 (100.0)	0.33	0.13, 0.52	0.001
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Cooked vegetables ¹	B = 9.0 (6.0, 13.5) C = 10.2 (6.7, 15.0)	785 (100.0)	0.16	-0.03, 0.35	0.10
Binary variable, 0 = low (<1/wk)* & 1 = high (>1 /wk)					
Potato containing dishes ²	B = 2.2 (1.2, 3.7) C = 2.2 (1.0, 3.5)	0 = 154 (24.2) 1 = 483 (75.8)	0.89	0.57, 1.39	0.60
Binary variable, 0 = low (<1/wk)* & high (1 = ≥1/wk)					
Potato palya ²	B = 0.7 (0.2, 1.0) C = 0.5 (0.0, 1.0)	0 = 341 (53.5) 1 = 296 (46.5)	0.74	0.50, 1.09	0.13
Continuous variable, square root transformed and z-standardised; units = SD					
Cooked Green leafy vegetables ¹	B = 3.0 (2.0, 4.7) C = 2.3 (1.2, 4.0)	785 (100.0)	-0.29	-0.49, 0.10	0.003
Continuous variable, square root transformed and z-standardised; units = SD					
Fresh fruit & fruit juices ¹	B = 23.2 (15.2, 35.5) C = 25.1 (16.6, 45.3)	785 (100.0)	0.29	0.09, 0.48	0.003
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Nuts & seeds ¹	B = 4.0 (2.0, 9.0) C = 7.0 (2.7, 12.2)	785 (100.0)	0.34	0.15, 0.53	0.001
3 categories variable, 0 = none, 1 = low (<1/wk) & 2 = high (≥1 - 3/wk)					
Fish & seafood ³	B = 0.0 (0.0, 0.5) C = 0.0 (0.0, 0.5)	0 = 473 (60.3) 1 = 178 (22.6) 2 = 134 (17.1)	0.68	0.46, 1.02	0.07
3 categories variable, 0 = low (<1/wk), 1 = medium (>1 - 3/wk) & 2 = high (> 3/wk)					

Table 4.1: Regression analysis of hospital as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups B = Baptist C = Cloudnine	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Hospital type Baptist (B) = 0, Cloudnine (C) = 1		
			β^1 / Odd s ratio ^{2,3}	95% CI	p
Egg and egg preparations ³	B = 2.0 (0.7, 4.0) C = 0.5 (0.0, 2.0)	0 = 302 (38.5) 1 = 256 (32.6) 2 = 227 (28.9)	0.37	0.25, 0.54	<0.001
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium (>1 -2/wk) & 3 = high (> 2 /wk)					
Poultry ³	B = 1.5 (0.5, 2.2) C = 0.0 (0.0, 1.7)	0 = 185 (23.6) 1 = 195 (24.8) 2 = 191 (24.3) 3 = 214 (27.3)	0.24	0.16, 0.34	<0.001
3 categories variable, 0 = none, 1 = low (<1 /wk) & 2 = medium (≥ 1 /wk)					
Meat ³	B = 0.2 (0.0, 1.0) C = 0.0 (0.0, 0.2)	0 = 367 (46.8) 1 = 200 (25.5) 2 = 218 (27.7)	0.35	0.23, 0.53	<0.001
Continuous variable, square root transformed and z-standardised; units = SD					
Milk & dairy products ¹	B = 18.5 (12.5, 26.2) C = 20.0 (14.7, 26.9)	785 (100.0)	0.14	-0.06, 0.33	0.16
Binary variable, 0 = none* & 1 = any					
Coffee ²	B = 0.0 (0.0, 7.0) C = 0.2 (0.0, 3.5)	0 = 332 (52.1) 1 = 305 (47.9)	1.34	0.91, 1.98	0.14
Continuous variable, square root transformed and z-standardised; units = SD					
Fried & fast food ¹	B = 6.5 (3.5, 11.0) C = 8.0 (4.1, 11.3)	785 (100.0)	0.11	-0.08, 0.31	0.25
Continuous variable, square root transformed and z-standardised; units = SD					
Added sugar, SSB & high sugar products ¹	B = 20.2 (12.7, 28.5) C = 18.5 (10.5, 25.5)	785 (100.0)	-0.08	-0.27, 0.11	0.41
Binary variable, 0 = none* & 1 = any					
Nutrient enriched powders ²	B = 20.2 (12.7, 28.5) C = 18.5 (10.5, 25.5)	0 = 568 (72.4) 1 = 217 (27.6)	2.34	1.57, 3.48	<0.001
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium (>1 -3/wk) & 4 = high (> 3 /wk)					
High salt products ³	B = 2.0 (0.2, 7.0) C = 2.1 (0.5, 5.5)	0 = 174 (22.2) 1 = 154 (19.6) 2 = 153 (19.5) 3 = 304 (38.7)	1.10	0.78, 1.56	0.59
3 categories variable, 0 = low (<1 /wk), 1 = medium (≥ 1 - 4/wk) & 2 = high (>4 /wk)					
Visible fat ³	B = 0.2 (0.0, 2.5) C = 2.0 (0.1, 7.0)	0 = 417 (53.1) 1 = 196 (25.0) 2 = 172 (21.9)	2.58	1.80, 3.71	<0.001

*Red text indicates reference group.

¹ Food groups in white=continuous; ² Food groups shaded in grey=binary variables; ³ Food groups shaded in blue= ordinal categorical variables.

Table 4.4: Regression analysis of Standard of Living (SLI) score as a predictor of frequency of intake of food groups (n=785)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Standard of Living (SLI) scores		
		β^1 / Odds ratio ^{2,3}	95% CI	p
Continuous variable, z-standardised; units = SD				
Milled cereals & products ¹	785 (100.0)	0.004	-0.01, 0.01	0.45
Binary variable, 0 = none* & 1 = any				
Wholegrain cereals ²	0=112 (14.3) 1= 673 (85.7)	1 1.04	- 1.01, 1.07	- 0.004
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Pulse & lentil preparations ¹	785 (100.0)	0.01	0.01, 0.02	0.002
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Salads & raw vegetables ¹	785 (100.0)	0.01	-0.001, 0.02	0.07
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Cooked vegetables ¹ :	785 (100.0)	0.02	0.01, 0.03	0.001
Binary variable, 0 = low ($\leq 1/\text{wk}$)* & 1 = high ($> 1/\text{wk}$)				
Potato containing dishes ²	0=185 (23.6) 1=600 (76.4)	1 0.99	- 0.98, 1.02	- 0.79
Binary variable, 0 = low ($< 1/\text{wk}$)* & high (1 = $\geq 1/\text{wk}$)				
Potato palya ²	0=407 (51.8) 1=378 (48.2)	1 1.00	- 0.99, 1.03	- 0.39
Continuous variable, square root transformed and z-standardised; units = SD				
Cooked Green leafy vegetables ¹	785 (100.0)	0.02	0.01, 0.03	0.001
Continuous variable, square root transformed and z-standardised; units = SD				
Fresh fruit, dried fruit & fruit juices ¹	785 (100.0)	0.01	0.01, 0.03	< 0.001
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Nuts & seeds ¹	785 (100.0)	0.01	-0.001, 0.02	0.08
3 categories variable, 0 = none, 1 = low ($< 1/\text{wk}$) & 2 = high ($\geq 1 - 3/\text{wk}$)				
Fish & seafood ³	0=473 (60.3) 1=178 (22.6) 2=134 (17.1)	0.99	0.97, 1.01	0.36
3 categories variable, 0 = low ($\leq 1/\text{wk}$), 1 = medium ($> 1 - 3/\text{wk}$) & 2 = high ($> 3/\text{wk}$)				
Egg and egg preparations ³	0=302 (38.5) 1=256 (32.6) 2=227 (28.9)	0.96	0.95, 0.98	< 0.001
4 categories variable, 0 = none, 1 = low ($\leq 1/\text{wk}$), 2 = medium ($> 1 - 2/\text{wk}$) & 3 = high ($> 2/\text{wk}$)				
Poultry ³	0=185 (23.6) 1=195 (24.8) 2=191 (24.3) 3=214 (27.3)	0.99	0.98, 1.00	0.60
3 categories variable, 0 = none, 1 = low ($< 1/\text{wk}$) & 2 = medium ($\geq 1/\text{wk}$)				
Meat ³	0=367 (46.8) 1=200 (25.5) 2=218 (27.7)	0.99	0.97, 1.00	0.35
Continuous variable, square root transformed and z-standardised; units = SD				
Milk & dairy products ¹	785 (100.0)	0.01	0.003, 0.02	0.01
Binary variable, 0 = none* & 1 = any				

Table 4.4: Regression analysis of Standard of Living (SLI) score as a predictor of frequency of intake of food groups (n=785)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Standard of Living (SLI) scores		
		β^1 / Odds ratio ^{2,3}	95% CI	p
Coffee ²	0=422 (53.8) 1=363 (46.2)	1 1.02	- 1.01, 1.05	- 0.009
Continuous variable, square root transformed and z-standardised; units = SD				
Fried & fast food ¹	785 (100.0)	0.01	0.001, 0.02	0.05
Continuous variable, square root transformed and z-standardised; units = SD				
Added sugar, SSB & high sugar products ¹	785 (100.0)	0.002	-0.01, 0.01	0.74
Binary variable, 0 = none* & 1 = any				
Nutrient enriched beverage supplements ²	0=568 (72.4) 1=217 (27.6)	1 1.03	- 1.00, 1.04	- 0.02
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium ($> 1-3$ /wk) & 4 = high (> 3 /wk)				
High salt products ³	0=174 (22.2) 1=154 (19.6) 2=153 (19.5) 3=304 (38.7)	0.98	0.97, 1.00	0.07
3 categories variable, 0 = low (< 1 /wk), 1 = medium ($\geq 1-4$ /wk) & 2 = high (> 4 /wk)				
Visible fat ³	0=417 (53.1) 1=196 (25.0) 2=172 (21.9)	1.04	1.01, 1.06	<0.001

*Red text indicates reference group.

¹ Food groups in white=continuous variables; ² Food groups shaded in grey=binary variables; ³ Food groups shaded in blue=ordinal categorical variables.

Table 4.5: Regression analysis of participant education as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores for continuous variables ¹ and categorical variables ^{2,3})	Predictor: Participant education level**				
	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each category ^{2,3}	β^1 / Odds ratio ²	95% CI	p
Milled cereals & products ¹ : Continuous variable, z-standardised; units = SD					
High school or less	37.5 (31.0, 47.1)	117 (14.9)	Reference	-	-
Intermediate and Pre-University	38.2 (31.0, 45.8)	137 (17.5)	0.01	-0.26, 0.23	0.90
Graduate	38.5 (31.3, 46.0)	312 (39.7)	-0.05	-0.25, 0.16	0.67
Post graduate	35.5 (28.7, 43.0)	219 (27.9)	-0.30	-0.52, -0.76	0.009
Wholegrain cereals ² : Binary variable, 0 = none* & 1 = any					
High school or less	7.0 (1.0, 7.0)	0=18 (15.4) 1=99 (84.6)	Reference	-	-

Table 4.5: Regression analysis of participant education as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores for continuous variables ¹ and categorical variables ^{2,3})	Predictor: Participant education level**				
	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each category ^{2,3}	β ¹ / Odds ratio ²	95% CI	p
Intermediate and Pre-University Graduate	7.0 (1.2, 8.1)	0=18 (13.1) 1=119 (86.9)	1.20	0.59, 2.43	0.60
Post graduate	5.0 (0.7, 8.0)	0=42 (13.5) 1=270 (86.5)	1.16	0.64, 2.12	0.60
	3.0 (0.5, 7.5)	0=34 (15.5) 1=185 (84.5)	0.99	0.53, 1.84	0.97
Pulse & lentil preparations ¹ : Continuous variable, log (x+1) transformed and z-standardised; units = SD					
High school or less	4.0 (2.6, 7.1)	117 (14.9)	Reference	-	-
Intermediate and Pre-University Graduate	4.0 (2.5, 7.2)	137 (17.5)	0.01	-0.24, 0.25	0.96
Post graduate	4.0 (2.5, 6.0)	312 (39.7)	-0.09	-0.30, 0.12	0.41
	4.0 (2.2, 8.0)	219 (27.9)	-0.04	-0.26, 0.18	0.75
Salads & raw vegetables ¹ : Continuous variable, log (x+1) transformed and z-standardised; units = SD					
High school or less	2.5 (1.2, 6.5)	117 (14.9)	Reference	-	-
Intermediate and Pre-University Graduate	3.0 (1.1, 5.3)	137 (17.5)	-0.01	-0.25, 0.24	0.97
Post graduate	3.0 (1.2, 7.0)	312 (39.7)	0.05	-0.16, 0.27	0.63
	3.0 (1.2, 7.0)	219 (27.9)	0.07	-0.15, 0.29	0.53
Cooked vegetables ¹ : Continuous variable, log (x+1) transformed and z-standardised; units = SD					
High school or less	9.5 (6.2, 13.6)	117 (14.9)	Reference	-	-
Intermediate and Pre-University Graduate	8.5 (5.8, 11.5)	137 (17.5)	-0.14	-0.39, 0.10	0.27
Post graduate	9.6 (6.2, 14.2)	312 (39.7)	0.03	-0.19, 0.24	0.81
	9.5 (6.2, 14.2)	219 (27.9)	-0.02	-0.24, 0.20	0.89
Potato containing dishes ² : Binary variable, 0 = low (≤ 1 /wk)* & 1 = high (> 1 /wk)					
High school or less	2.2 (1.2, 3.5)	0=26 (22.2) 1=91 (77.8)	Reference	-	-
Intermediate and Pre-University Graduate	2.2 (1.2, 3.5)	0=33 (24.1) 1=104 (75.9)	0.90	0.50, 1.16	0.73
Post graduate	2.2 (1.2, 4.0)	0=69 (22.1) 1=243 (77.9)	1.00	0.60, 1.67	0.98
	2.0 (1.0, 3.5)	0=57 (26.0) 1=162 (74.0)	0.81	0.47, 1.38	0.44
Potato palya ² : Binary variable, 0 = low (< 1 /wk)* & high (1 = ≥ 1 /wk)					
High school or less	0.7 (0.2, 1.0)	0=60 (51.3) 1=57 (48.7)	Reference	-	-
Intermediate and Pre-University Graduate	0.5 (0.2, 1.0)	0=72 (52.6) 1=65 (47.4)	0.95	0.58, 1.56	0.84
Post graduate	0.7 (0.2, 1.0)	0=158 (50.6) 1=154 (49.4)	1.03	0.67, 1.57	0.91
	0.5 (0.2, 1.0)	0=117 (53.4) 1=102 (46.6)	0.92	0.59, 1.44	0.70

Table 4.5: Regression analysis of participant education as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores for continuous variables ¹ and categorical variables ^{2,3})	Predictor: Participant education level**				
	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each category ^{2,3}	β ¹ / Odds ratio ²	95% CI	p
Cooked Green leafy vegetables ¹: Continuous variable, square root transformed and z-standardised; units = SD					
High school or less	3.0 (2.0, 5.0)	117 (14.9)	Reference	-	-
Intermediate and Pre-University	3.0 (2.0, 5.0)	137 (17.5)	0.01	-0.24, 0.26	0.91
Graduate	3.0 (2.0, 4.5)	312 (39.7)	-0.03	-0.24, 0.19	0.80
Post graduate	3.0 (2.0, 4.5)	219 (27.9)	-0.08	-0.31, 0.14	0.47
Fresh fruit, dried fruit & fruit juices ¹: Continuous variable, square root transformed and z-standardised; units = SD					
High school or less	20.0 (13.8, 33.1)	117 (14.9)	Reference	-	-
Intermediate and Pre-University	22.0 (14.3, 34.7)	137 (17.5)	0.03	-0.22, 0.28	0.81
Graduate	24.7 (16.8, 37.6)	312 (39.7)	0.17	-0.04, 0.39	0.11
Post graduate	23.2 (14.5, 39.2)	219 (27.9)	0.17	-0.05, 0.39	0.15
Nuts & seeds ¹: Continuous variable, log (x+1) transformed and z-standardised; units = SD					
High school or less	3.2 (1.3, 7.3)	117 (14.9)	Reference	-	-
Intermediate and Pre-University	4.0 (2.2, 8.3)	137 (17.5)	0.18	-0.06, 0.42	0.15
Graduate	4.2 (2.0, 10.0)	312 (39.7)	0.28	0.06, 0.49	0.010
Post graduate	6.0 (2.2, 12.0)	219 (27.9)	0.40	0.17, 0.62	<0.001
Fish & seafood ³: 3 categories variable, 0 = none, 1 = low (<1/wk) & 2 = high ($\geq 1 - 3$/wk)					
High school or less	0.0 (0.0, 0.2)	0 = 65 (55.6) 1 = 32 (27.3) 2 = 20 (17.1)	1.00	-0.13, 0.14	0.90
Intermediate and Pre-University	0.0 (0.0, 0.2)	0 = 86 (62.8) 1 = 41 (29.9) 2 = 10 (7.3)			
Graduate	0.0 (0.0, 0.5)	0 = 190 (60.9) 1 = 62 (19.9) 2 = 60 (19.2)			
Post graduate	0.0 (0.0, 0.5)	0 = 132 (60.3) 1 = 43 (19.6) 2 = 44 (20.1)			
Egg and egg preparations ³: 3 categories variable, 0 = low (≤ 1/wk), 1 = medium (>1 - 3/wk) & 2 = high (> 3/wk)					
High school or less	2.0 (0.5, 4.0)	0 = 49 (41.9) 1 = 31 (26.5) 2 = 37 (31.6)	0.99	0.88, 1.14	0.99
Intermediate and Pre-University	1.7 (0.3, 3.0)	0 = 53 (38.7) 1 = 52 (38.0) 2 = 32 (23.3)			

Table 4.5: Regression analysis of participant education as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores for continuous variables ¹ and categorical variables ^{2,3})	Predictor: Participant education level**				
	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each category ^{2,3}	β ¹ / Odds ratio ²	95% CI	p
Graduate	2.0 (0.5, 4.0)	0 = 108 (34.6) 1 = 107 (34.3) 2 = 97 (31.1)			
Post graduate	1.5 (0.5, 3.5)	0 = 92 (42.0) 1 = 66 (30.1) 2 = 61 (27.9)			
Poultry ³: 4 categories variable, 0 = none, 1 = low (≤ 1/wk), 2 = medium (>1-2/wk) & 3 = high (> 2/wk)					
High school or less	1.5 (0.5, 2.2)	0 = 35 (29.9) 1 = 18 (15.4) 2 = 19 (16.2) 3 = 45 (38.5)	0.84	0.74, 1.04	0.008
Intermediate and Pre-University	1.0 (0.2, 2.0)	0 = 35 (25.5) 1 = 18 (13.1) 2 = 21 (15.3) 3 = 63 (46.1)			
Graduate	1.5 (0.2, 2.5)	0 = 64 (20.5) 1 = 61 (19.6) 2 = 63 (20.2) 3 = 124 (39.7)			
Post graduate	1.0 (0.0, 2.0)	0 = 40 (18.3) 1 = 57 (26.0) 2 = 50 (22.8) 3 = 72 (32.9)			
Meat ³: 3 categories variable, 0 = none, 1 = low (<1/wk), 2 = medium (≥ 1/wk)					
High school or less	0.5 (0.0, 1.2)	0 = 43 (36.8) 1 = 30 (25.6) 2 = 44 (37.6)	0.81	0.71, 0.92	0.002
Intermediate and Pre-University	0.2 (0.0, 0.7)	0 = 62 (45.3) 1 = 42 (30.6) 2 = 33 (24.1)			
Graduate	0.2 (0.0, 1.0)	0 = 143 (45.7) 1 = 75 (24.0) 2 = 94 (30.1)			
Post graduate	0.0 (0.0, 0.7)	0 = 119 (54.3) 1 = 53 (24.2) 2 = 47 (21.5)			
Milk & dairy products ¹: Continuous variable, square root transformed and z-standardised; units = SD					
High school or less	19.5 (14.5, 29.0)	117 (14.9)	Reference	-	-
Intermediate and Pre-University	18.2 (11.2, 26.6)	137 (17.5)	-0.17	-0.42, 0.07	0.16
Graduate	18.5 (12.7, 27.3)	312 (39.7)	-0.01	-0.22, 0.19	0.90

Table 4.5: Regression analysis of participant education as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores for continuous variables ¹ and categorical variables ^{2,3})	Predictor: Participant education level**				
	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each category ^{2,3}	β ¹ / Odds ratio ²	95% CI	p
Post graduate	18.5 (13.0, 25.0)	219 (27.9)	-0.07	-0.29, 0.15	0.56
Coffee ² : Binary variable, 0 = none & 1 = any					
High school or less	0.0 (0.0, 7.0)	0 = 71 (60.7) 1 = 46 (39.3)	Reference	-	-
Intermediate and Pre-University	0.0 (0.0, 7.0)	0 = 72 (52.6) 1 = 65 (47.4)	1.39	0.85, 2.30	0.19
Graduate	0.2 (0.0, 7.0)	0 = 155 (49.7) 1 = 157 (50.3)	1.56	1.02, 2.40	0.04
Post graduate	0.0 (0.0, 3.0)	0 = 124 (56.6) 1 = 95 (43.4)	1.18	0.75, 1.87	0.47
Fried & fast food ¹ : Continuous variable, square root transformed and z-standardised; units = SD					
High school or less	5.7 (3.5, 11.0)	117 (14.9)	Reference	-	-
Intermediate and Pre-University	7.2 (3.5, 11.6)	137 (17.5)	0.07	-0.17, 0.32	0.58
Graduate	7.0 (4.0, 11.5)	312 (39.7)	0.09	-0.11, 0.31	0.37
Post graduate	6.2 (3.0, 10.2)	219 (27.9)	-0.07	-0.29, 0.15	0.53
Added sugar, SSB & high sugar products ¹ : Continuous variable, square root transformed and z-standardised; units = SD					
High school or less	23.2 (16.0, 31.0)	117 (14.9)	Reference	-	-
Intermediate and Pre-University	19.0 (10.7, 27.1)	137 (17.5)	-0.31	-0.55, 0.06	0.01
Graduate	19.5 (12.8, 27.6)	312 (39.7)	-0.21	-0.42, -0.001	0.05
Post graduate	18.2 (10.7, 26.2)	219 (27.9)	-0.35	-0.57, -0.12	0.002
Nutrient enriched beverage supplements ² : Binary variable, 0 = none* & 1 = any					
High school or less	0.0 (0.0, 0.0)	0 = 97 (82.9) 1 = 20 (17.1)	Reference	-	-
Intermediate and Pre-University	0.0 (0.0, 0.0)	0 = 108 (78.8) 1 = 29 (21.2)	1.30	0.69, 2.45	0.41
Graduate	0.0 (0.0, 0.5)	0 = 233 (74.7) 1 = 79 (25.3)	1.64	0.95, 2.84	0.074
Post graduate	0.0 (0.0, 7.0)	0 = 130 (59.4) 1 = 89 (40.6)	3.32	1.91, 5.77	<0.001
High salt products ³ : 4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium ($> 1-3$ /wk) & 4 = high (> 3 /wk)					
High school or less	2.0 (0.0, 7.0)	0 = 35 (29.9) 1 = 18 (15.4) 2 = 19 (16.2) 3 = 45 (38.5)	0.99	0.88, 1.13	0.97

Table 4.5: Regression analysis of participant education as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores for continuous variables ¹ and categorical variables ^{2,3})	Predictor: Participant education level**				
	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each category ^{2,3}	β ¹ / Odds ratio ²	95% CI	p
Intermediate and Pre-University	3.0 (0.0, 7.0)	0 = 35 (25.5) 1 = 18 (13.1) 2 = 21 (15.4) 3 = 63 (46.0)			
Graduate	2.0 (0.2, 7.0)	0 = 64 (20.5) 1 = 61 (19.6) 2 = 63 (20.2) 3 = 124 (39.7)			
Post graduate	1.7 (0.5, 5.0)	0 = 40 (18.3) 1 = 57 (26.0) 2 = 50 (22.8) 3 = 72 (32.9)			
Visible fat ³ : 3 categories variable, 0 = low (<1/wk), 1 = medium ($\geq$ 1- 4/wk) & 2 = high (>4/wk)					
High school or less	0.2 (0.0, 2.2)	0 = 70 (59.8) 1 = 26 (22.3) 2 = 21 (17.9)	1.13	0.99, 1.30	0.05
Intermediate and Pre-University	0.2 (0.0, 2.5)	0 = 83 (60.6) 1 = 26 (19.0) 2 = 28 (20.4)			
Graduate	1.0 (0.0, 3.0)	0 = 149 (47.8) 1 = 91 (29.2) 2 = 72 (23.0)			
Post graduate	0.5 (0.0, 3.0)	0 = 115 (52.5) 1 = 53 (24.2) 2 = 51 (23.3)			

*Red test indicates reference group.

High school and less = minimum 8 years; Intermediate and Pre-University = minimum 12 years; Graduation = minimum 15 years; Post-graduation = minimum 18 years of education.

¹ Food groups in white=continuous variables; ² Food groups shaded in grey=binary variables; ³ Food groups shaded in blue=ordinal categorical variables.

Table 4.6: Regression analysis area of residence as a predictor of frequency of intake of food groups (N=772*)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Area of residence: Urban(U) = 0; Rural(R) = 1		
			β ¹ / Odds ratio ^{2,3}	95% CI	p

Continuous variable, z-standardised; units = SD

Table 4.6: Regression analysis area of residence as a predictor of frequency of intake of food groups (N=772*)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Area of residence: Urban(U) = 0; Rural(R) = 1		
			β^1 / Odds ratio ^{2,3}	95% CI	p
Milled cereals & products ¹	U = 36.7 (29.5, 44.7) R = 38.7 (31.5, 45.6)	772 (100.0)	0.13	-0.02, 0.28	0.09
Binary variable, 0 = none* & 1 = any					
Wholegrain cereals ²	U = 2.5 (0.2, 7.2) R = 7.2 (4.0, 12.0)	0=110 (14.2) 1=662 (85.8)	1 4.09	- 2.20, 7.61	- <0.001
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Pulse & lentil preparations ¹	U = 4.0 (2.2, 7.0) R = 4.0 (3.0, 7.0)	772 (100.0)	0.18	0.03, 0.34	0.02
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Salads & raw vegetables ¹	U = 3.0 (1.2, 7.0) R = 3.0 (1.2, 6.0)	772 (100.0)	-0.02	-0.17, 0.14	0.85
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Cooked vegetables ¹	U = 9.5 (6.2, 14.0) R = 9.0 (6.0, 13.5)	772 (100.0)	-0.07	-0.23, 0.08	0.35
Binary variable, 0 = low (<1/ wk)* & 1 = high (>1/wk)					
Potato containing dishes ²	U = 2.2 (1.2, 3.7) R = 2.0 (1.2, 3.5)	182 (23.6) 590 (76.4)	1 0.90	- 0.63, 1.30	- 0.57
Binary variable, 0 = low (<1/wk)* & high (1 = ≥1/wk)					
Potato palya ²	U = 0.7 (0.2, 1.0) R = 0.7 (0.2, 1.0)	0=401 (51.9) 1=371 (48.1)	1 0.95	- 0.70, 1.30	- 0.76
Continuous variable, square root transformed and z-standardised; units = SD					
Cooked Green leafy vegetables ¹	U = 2.7 (1.7, 4.2) R = 3.5 (2.2, 5.0)	772 (100.0)	0.31	0.15, 0.46	<0.001
Continuous variable, square root transformed and z-standardised; units = SD					
Fresh fruit, dried fruit & fruit juices ¹	U = 20.0 (12.5, 31.2) R = 21.2 (12.6, 30.7)	772 (100.0)	0.04	-0.11, 0.19	0.59
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Nuts & seeds ¹	U = 5.0 (2.2, 10.2) R = 4.0 (2.0, 8.2)	772 (100.0)	-0.18	-0.34, 0.03	0.01
3 categories variable, 0 = none, 1 = low (<1/wk) & 2 = high (≥1 - 3/wk)					
Fish & seafood ³	U = 0.0 (0.0, 0.5) R = 0.0 (0.0, 0.2)	0=466 (60.4) 1=173 (22.4) 2=133 (17.2)	0.51	0.37, 0.70	<0.001
3 categories variable, 0 = low (<1/wk), 1 = medium (>1 - 3/wk) & 2 = high (>3/wk)					
Egg and egg preparations ³	U = 2.0 (0.5, 4.0) R = 1.5 (0.5, 3.0)	0=301 (39.0) 1=250 (32.4) 2=221 (28.6)	0.76	0.57, 1.01	0.05
4 categories variable, 0 = none, 1 = low (≤ 1/wk), 2 = medium (>1-2/wk) & 3 = high (>2/wk)					
Poultry ³	U = 1.2 (0.0, 2.2) R = 1.0 (0.2, 2.2)	0=185 (24.0) 1=193 (25.0) 2=183 (23.7) 3=211 (27.3)	0.95	0.72, 1.24	0.69
3 categories variable, 0 = none, 1 = low (<1/wk) & 2 = medium (≥1/wk)					
Meat ³	U = 0.3 (0.0, 1.0) R = 0.3 (0.0, 1.0)	0=361 (46.8) 1=195 (25.3)	0.87	0.65, 1.15	0.33

Table 4.6: Regression analysis area of residence as a predictor of frequency of intake of food groups (N=772*)

Intake of food groups (N=772)			Predictor: Area of residence: Urban(U) = 0; Rural(R) = 1		
Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	β^1 / Odds ratio ^{2,3}	95% CI	p
2=216 (28.0)					
Continuous variable, square root transformed and z-standardised; units = SD					
Milk & dairy products ¹	U = 19.0 (12.7, 26.0) R = 18.5 (14.0, 28.3)	772 (100.0)	0.08	-0.07, 0.24	0.29
Binary variable, 0 = none* & 1 = any					
Coffee ²	U = 0.0 (0.0, 7.0) R = 0.0 (0.0, 7.0)	0=414 (53.6) 1=358 (46.4)	1 1.16	- 0.85,1.57	- 0.35
Continuous variable, square root transformed and z-standardised; units = SD					
Fried & fast food ¹	U = 6.7 (3.7, 11.0) R = 6.7 (3.5, 11.2)	772 (100.0)	-0.01	-0.16, 0.14	0.89
Continuous variable, square root transformed and z-standardised; units = SD					
Added sugar, SSB & high sugar products ¹	U = 20.2 (12.5, 28.7) R = 19.2 (11.1, 27.5)	772 (100.0)	-0.08	-0.23, 0.07	0.32
Binary variable, 0 = none* & 1 = any					
Nutrient enriched beverage supplements ²	U = 0.0 (0.0, 1.0) R = 0.0 (0.0, 0.0)	0=559 (72.4) 1=213 (27.6)	1 0.68	- 0.47, 0.96	- 0.03
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium ($>1-3$ /wk) & 4 = high (>3 /wk)					
High salt products ³	U = 2.2 (0.5, 7.0) R = 1.0 (0.0, 7.0)	0=170 (22.0) 1=153 (19.8) 2=151 (19.6) 3=298 (38.6)	0.59	0.44, 0.77	<0.001
3 categories variable, 0=low (<1 /wk), 1 = medium ($\geq 1-4$ /wk) and 2 = high (>4 /wk)					
Visible fat ³	U = 0.5 (0.0, 3.0) R = 0.2 (0.0, 3.0)	0=409 (53.0) 1=192 (24.9) 2=171 (22.1)	0.89	0.66, 1.19	0.43
*Residence data missing for 13 women. *Red text indicates reference group.					
¹ Food groups in white=continuous variables; ² Food groups shaded in grey=binary variables;					
³ Food groups shaded in blue=ordinal categorical variables.					

Table 4.7: Regression analysis of family type as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2, 3})	Median (IQR) intakes of food groups N=Nuclear J=Joint	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2, 3}	Predictor: Family type Nuclear (N) = 0; Joint (J) = 1		
			β ¹ / Odds ratio ^{2, 3}	95% CI	p
			Continuous variable, z-standardised; units = SD		
Milled cereals & products ¹	N = 36.2 (29.5, 43.8) J = 39.0 (31.3, 46.6)	785 (100.0)	0.22	0.07, 0.35	0.002
Binary variable, 0 = none* & 1 = any					

Table 4.7: Regression analysis of family type as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups N=Nuclear J=Joint	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Family type Nuclear (N) = 0; Joint (J) = 1		
			β^1 / Odds ratio ^{2,3}	95% CI	p
Wholegrain cereals ²	N = 3.0 (0.5, 7.5) J = 7.0 (1.0, 8.1)	0=112 (14.3) 1=673 (85.7)	1 2.00	- 1.31, 3.08	- 0.001
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Pulse & lentil preparations ¹	N = 4.0 (2.2, 7.0) J = 4.0 (3.0, 7.0)	785 (100.0)	0.13	-0.01, 0.28	0.05
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Salads & raw vegetables ¹	N = 3.0 (1.1, 7.0) J = 3.0 (1.5, 6.0)	785 (100.0)	0.03	-0.10, 0.17	0.59
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Cooked vegetables ¹	N = 9.5 (6.0, 13.5) J = 9.3 (6.2, 14.2)	785 (100.0)	0.05	-0.09, 0.19	0.49
Binary variable, 0 = low (≤ 1 /wk)* & 1 = high (> 1 /wk)					
Potato containing dishes ²	N=2.2 (1.2, 3.7) J=2.2(1.2, 3.5)	0=185 (23.6) 1=600 (76.4)	1 1.05	- 0.75, 1.47	- 0.75
Binary variable, 0 = low (< 1 /wk)* & high (1 = ≥ 1 /wk)					
Potato palya ²	N=0.7 (0.2, 1.0) J=0.7 (0.2, 1.0)	0=407 (51.8) 1=378 (48.2)	1 1.07	- 0.81, 1.42	- 0.61
Continuous variable, square root transformed and z-standardised; units = SD					
Cooked Green leafy vegetables ¹	N = 3.0 (2.0, 4.3) J = 3.0 (2.0, 5.0)	785 (100.0)	0.20	0.06, 0.34	0.004
Continuous variable, square root transformed and z-standardised; units = SD					
Fresh fruit, dried fruit & fruit juices ¹	N = 21.0 (12.7, 31.1) J = 19.5 (12.2, 31.1)	785 (100.0)	0.00	-0.14, 0.14	0.99
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Nuts & seeds ¹	N = 4.5 (2.2, 10.0) J = 4.0 (2.0, 10.0)	785 (100.0)	-0.05	-0.19, 0.08	0.41
3 categories variable, 0 = none, 1 = low (< 1 /wk) & 2 = high ($\geq 1 - 3$ /wk)					
Fish & seafood ³	N = 0.0 (0.0, 0.5) J = 0.0 (0.0, 0.2)	0=473 (60.3) 1=178 (22.7) 2=134 (17.0)	0.61	0.46, 0.81	0.001
3 categories variable, 0 = low (≤ 1 /wk), 1 = medium ($> 1 - 3$ /wk) & 2 = high (> 3 /wk)					
Egg and egg preparations ³	N = 2.0 (0.7, 3.5) J = 1.5 (0.2, 3.6)	0=302 (38.5) 1=256 (32.6) 2=227 (28.9)	0.76	0.59, 0.99	0.04
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium ($> 1-2$ /wk) & 3 = high (> 2 /wk)					
Poultry ³	N = 1.2 (0.2, 2.2) J = 1.2 (0.2, 2.2)	0=185 (23.6) 1=195 (24.8) 2=191 (24.3) 3=214 (27.3)	1.04	0.81, 1.34	0.74
3 categories variable, 0 = none, 1 = low (< 1 /wk) & 2 = medium (≥ 1 /wk)					
Meat ³	N = 0.2 (0.0, 1.0) J = 0.1 (0.0, 1.0)	0=367 (46.8) 1=200 (25.5) 2=218 (27.7)	0.86	0.66, 1.12	0.27
Continuous variable, square root transformed and z-standardised; units = SD					
Milk & dairy products ¹	N = 19.0 (13.1, 26.5) J = 18.0 (12.5, 26.2)	785 (100.0)	-0.08	-0.22, 0.05	0.26

Table 4.7: Regression analysis of family type as a predictor of frequency of intake of food groups (N=785)

Food groups (N=785)			Predictor: Family type Nuclear (N) = 0; Joint (J) = 1		
Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups N=Nuclear J=Joint	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	β^1 / Odds ratio ^{2,3}	95% CI	p
Binary variable, 0 = none* & 1 = any					
Coffee ²	N = 0.0 (0.0, 0.7) J = 0.0 (0.0, 7.0)	785 (100.0)	1 0.82	- 0.61, 1.08	- 0.17
Continuous variable, square root transformed and z-standardised; units = SD					
Fried & fast food ¹	N = 6.2 (3.5, 11.0) J = 7.1 (3.7, 11.2)	785 (100.0)	0.07	-0.06, 0.21	0.27
Continuous variable, square root transformed and z-standardised; units = SD					
Added sugar, SSB and high sugar products ¹	N = 19.7 (13.0) J = 20.0 (10.8, 28.0)	N = 429 (54.6) J = 356 (45.4)	-0.09	-0.23, 0.04	0.17
Binary variable, 0 = none* & 1 = any					
Nutrient enriched supplements ²	N = 0.0 (0.0, 1.0) J = 0.0 (0.0, 0.9)	0=568 (72.4) 1=217 (27.6)	1 0.91	- 0.66, 1.25	- 0.59
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium ($>1-3$ /wk) & 4 = high (>3 /wk)					
High salt products ³	N = 2.5 (0.5, 7.0) J = 1.5 (0.2, 7.0)	0=174 (22.2) 1=154 (19.6) 2=153 (19.5) 3=304 (38.7)	0.72	0.56, 0.93	0.01
3 categories variable, 0 = low (<1 /wk), 1 = medium ($\geq 1-4$ /wk) & 2 = high (>4 /wk)					
Visible fat ³	N = 0.7 (0.0, 3.0) J = 0.2 (0.0, 3.0)	417 (53.1) 196 (25.0) 172 (21.9)	0.91	1.43, 1.19	0.51

*Red text indicates reference group.

¹ Food groups in white=continuous variables; ² Food groups shaded in grey=binary variables; ³ Food groups shaded in blue=ordinal categorical variables.

Table 4.8: Regression analysis of age as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: age (in years)		
		β ¹ / Odds ratio ^{2,3}	95% CI	p
Continuous variable, z-standardised; units = SD				
Milled cereals & products ¹ :	785 (100.0)	-0.02	-0.04, -0.01	0.004
Binary variable, 0 = none* & 1 = any				
Wholegrain cereals ²	0=112 (14.3)	1	-	-
	1=673 (85.7)	1.00	0.96, 1.05	0.76
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Pulse & lentil preparations ¹	785 (100.0)	0.02	0.004, 0.04	0.01
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Salads & raw vegetables ¹ :	785 (100.0)	0.02	0.004, 0.04	0.01
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Cooked vegetables ¹ :	785 (100.0)	0.03	0.02, 0.05	<0.001

Table 4.8: Regression analysis of age as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: age (in years)		
		β ¹ / Odds ratio ^{2,3}	95% CI	p
Binary variable, 0 = low (<1/wk)* & 1 = high (≥1/wk)				
Potato containing dishes ² :	185 (23.6)	1	-	-
	600 (76.4)	0.99	0.96, 1.03	0.77
Binary variable, 0 = low (≤1/wk)* & high (1 = >1/wk)				
Potato palya ² :	407 (51.8)	1	-	-
	378 (48.2)	1.02	0.99, 1.05	0.26
Continuous variable, square root transformed and z-standardised; units = SD				
Cooked Green leafy vegetables ¹	785 (100.0)	0.002	-0.01, 0.02	0.76
Continuous variable, square root transformed and z-standardised; units = SD				
Fresh fruit, dried fruit & fruit juices ¹ :	785 (100.0)	0.02	0.01, 0.04	0.006
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Nuts & seeds ¹ :	785 (100.0)	0.04	0.03, 0.06	<0.001
3 categories variable, 0 = none, 1 = low (<1/wk) & 2 = high (≥1 - 3/wk)				
Fish & seafood ³ :	473 (60.3)	1.06	1.03, 1.10	<0.001
	178 (22.7)			
	134 (17.0)			
3 categories variable, 0 = low (≤1/wk), 1 = medium (>1- 3/wk) & 2 = high (>3/wk)				
Egg and egg preparations ³ :	302 (38.5)	1.03	1.00, 1.06	0.04
	256 (32.6)			
	227 (28.9)			
4 categories variable, 0 = none, 1 = low (≤ 1/wk), 2 = medium (>1-2/wk) & 3 = high (>2/ wk)				
Poultry ³	185 (23.6)	0.98	0.96, 1.01	0.29
	195 (24.8)			
	191 (24.3)			
	214 (27.3)			
3 categories variable, 0 = none, 1 = low (<1/ wk) & 2 = medium (≥1/ wk)				
Meat ³	367 (46.8)	0.99	0.96, 1.03	0.72
	200 (25.5)			
	218 (27.7)			
Continuous variable, square root transformed and z-standardised; units = SD				
Milk & dairy products ¹ :	785 (100.0)	-0.01	-0.02, 0.01	0.39
Binary variable, 0 = none* & 1 = any				
Coffee ²	422 (53.8)	1	-	-
	363 (46.2)	1.05	1.01, 1.08	0.007
Continuous variable, square root transformed and z-standardised; units = SD				
Fried & fast food ¹ :	785 (100.0)	0.01	-0.01, 0.03	0.27
Continuous variable, square root transformed and z-standardised; units = SD				
Added sugar, SSB & high sugar products ¹	785 (100.0)	0.02	0.01, 0.04	0.01
Binary variable, 0 = none* & 1 = any				
Nutrient enriched beverage supplements ²	568 (72.4)	1	-	-
	217 (27.6)	1.03	0.99, 1.07	0.16
4 categories variable, 0 = none, 1 = low (≤1/wk), 2 = medium (>1-3/wk) & 4 = high (>3/ wk)				
High salt products ³	174 (22.2)	1.03	1.00, 1.06	0.04
	154 (19.6)			

Table 4.8: Regression analysis of age as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: age (in years)		
		β^1 / Odds ratio ^{2,3}	95% CI	p
	153 (19.5)			
	304 (38.7)			
3 categories variable, 0 = low (<1/wk), 1 = medium ($\geq 1 - 4$ /wk) & 2 = high (>4/ wk)				
Visible fat ³	417 (53.1)	1.03	1.00, 1.07	0.03
	196 (25.0)			
	172 (21.9)			

***Red text indicates reference group.**
¹ Food groups in white=continuous variables; ² Food groups shaded in grey=binary variables; ³ Food groups shaded in blue=ordinal categorical variables.

Table 4.9: Regression analysis of BMI as predictor of frequency of intake of food groups (N=762)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2, 3})	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2, 3}	Predictor: BMI (in Kg/m ²)		
		β ¹ / Odds ratio ^{2, 3}	95% CI	p
Continuous variable, z-standardised; units = SD				
Milled cereals & products ¹	762 (100.0)	-0.02	-0.04, -0.01	0.001
Binary variable, 0 = none* and 1 = any				
Wholegrain cereals ² :	109 (14.3)	1	-	-
	653 (85.7)	1.02	0.98, 1.07	0.37
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Pulse & lentil preparations ¹	762 (100.0)	-0.007	-0.02, 0.01	0.39
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Salads & raw vegetables ¹ :	762 (100.0)	0.009	-0.006, 0.02	0.25
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Cooked vegetables ¹	762 (100.0)	0.01	-0.004, 0.02	0.14
Binary variable, 0 = low (<1/wk)* and 1 = high (>1/wk)				
Potato containing dishes ²	179 (23.5)	1	-	-
	583 (76.5)	0.96	0.93, 0.99	0.03
Binary variable, 0 = low (<1/wk)* and high (1 = ≥ 1 /wk)				
Potato palya ²	396 (52.0)	1	-	-
	366 (48.0)	0.99	0.96, 1.11	0.40
Continuous variable, square root transformed and z-standardised; units = SD				
Cooked Green leafy vegetables ¹	762 (100.0)	-0.01	-0.03, 0.004	0.13
Continuous variable, square root transformed and z-standardised; units = SD				
Fresh fruit, dried fruit & fruit juices ¹	762 (100.0)	-0.02	-0.04, -0.005	0.009
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Nuts & seeds ¹	762 (100.0)	-0.008	-0.02, 0.01	0.32
3 categories variable, 0 = none, 1 = low (<1/wk) & 2 = high ($\geq 1 - 3$ /wk)				
Fish & seafood ³	458 (60.1)	1.02	0.99, 1.06	0.12
	173 (22.7)			
	131 (17.2)			
3 categories variable, 0 = low (<1/wk), 1 = medium (>1-3/wk) & 2 = high (>3/ wk)				

Table 4.9: Regression analysis of BMI as predictor of frequency of intake of food groups (N=762)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2, 3})	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2, 3}	Predictor: BMI (in Kg/m ²)		
		β ¹ / Odds ratio ^{2, 3}	95% CI	p
Egg and egg preparations ³	293 (38.5) 251 (32.9) 218 (28.6)	1.01	0.98, 1.03	0.49
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium ($>1-2$ /wk) & 3 = high (>2 /wk)				
Poultry ³	178 (23.4) 188 (24.7) 184 (24.1) 212 (27.8)	0.99	0.96, 1.02	0.66
3 categories variable, 0 = none, 1 = low (<1 /wk), 2 = medium (≥ 1 /wk)				
Meat ³	353 (46.3) 196 (25.7) 213 (28.0)	1.01	0.98, 1.04	0.42
Continuous variable, square root transformed and z-standardised; units = SD				
Milk & dairy products ¹	762 (100.0)	-0.02	-0.04, -0.01	0.002
Binary variable, 0 = none* & 1 = any				
Coffee ²	407 (53.4) 355 (46.6)	1 1.07	- 1.03, 1.10	- <0.001
Continuous variable, square root transformed and z-standardised; units = SD				
Fried & fast food ¹ :	762 (100.0)	0.004	-0.01, 0.02	0.63
Continuous variable, square root transformed and z-standardised; units = SD				
Added sugar, SSB & high sugar products ¹	762 (100.0)	-0.001	-0.02, 0.02	0.93
Binary variable, 0 = none* & 1 = any				
Nutrient enriched beverage supplements ²	555 (72.8) 207 (27.2)	1 0.98	- 0.95, 1.11	- 0.34
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium ($>1-3$ /wk) & 4 = high (>3 /wk)				
High salt products ³	172 (22.6) 148 (19.4) 148 (19.4) 294 (38.6)	0.98	0.96, 1.45	0.37
3 categories variable, 0 = low (<1 /wk), 1 = medium ($\geq 1-4$ /wk) & 2 = high (>4 /wk)				
Visible fat ³	403 (52.9) 190 (24.9) 169 (22.2)	0.97	0.95, 1.00	0.08

*Red text indicates reference group.

¹ Food groups in white=continuous variables; ² Food groups shaded in grey=binary variables;³ Food groups shaded in blue=ordinal categorical variables.

Table 4.10: Regression analysis of physical activity as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Walking per week (in minutes) (no walking/week = 0, Between 1 & 150 minutes/ week = 1, >150 minutes/week =2)		
		β ¹ / Odds ratio ^{2,3}	95% CI	p
Continuous variable, z-standardised; units = SD				
Milled cereals & products ¹	785 (100.0)	-0.08	-0.19, 0.02	0.15
Binary variable, 0 = none* & 1 = any				
Wholegrain cereals ²	0 = 112 (14.4)	1	-	-
	1 = 668 (85.6)	0.95	0.73, 1.23	0.71
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Pulse & lentil preparations ¹	785 (100.0)	0.08	-0.02, 0.20	0.13
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Salads & raw vegetables ¹	785 (100.0)	0.16	0.05, 0.27	0.004
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Cooked vegetables ¹	785 (100.0)	-0.01	-0.12, 0.09	0.78
Binary variable, 0 = low (<1/wk)* & 1 = high (>1/wk)				
Potato containing dishes ²	0 = 154 (24.2)	1	-	-
	1 = 483 (75.8)	1.14	0.87, 1.49	0.34
Binary variable, 0 = low (<1/wk)* & high (1 =≥1/wk)				
Potato palya ²	0 = 341 (53.5)	1	-	-
	1 = 296 (46.5)	1.04	0.83, 1.30	0.72
Continuous variable, square root transformed and z-standardised; units = SD				
Cooked Green leafy vegetables ¹	785 (100.0)	0.08	-0.03, 0.19	0.16
Continuous variable, square root transformed and z-standardised; units = SD				
Fresh fruit & fruit juices ¹	785 (100.0)	0.07	-0.03, 0.18	0.20
Continuous variable, log (x+1) transformed and z-standardised; units = SD				
Nuts & seeds ¹	785 (100.0)	0.10	-0.00, 0.22	0.06
3 categories variable, 0 = none, 1 = low (<1/wk) & 2 = high (≥1 - 3/wk)				
Fish & seafood ³	0 = 387 (60.8)	1.11	1.12, 1.38	0.35
	1 = 142 (22.3)			
	2 = 108 (17.0)			
3 categories variable, 0 = low (<1/wk), 1 = medium (>1 - 3/wk) & 2 = high (>3/ wk)				
Egg and egg preparations ³	0 = 252 (39.6)	1.06	0.86, 1.30	0.58
	1 = 200 (31.4)			
	2 = 185 (29.0)			
4 categories variable, 0 = none, 1 = low (<= 1/wk), 2 = medium (>1-2/wk) & 3 = high (> 2/wk)				
Poultry ³	0 = 161(25.3)	0.87	0.70, 0.94	0.17
	1 = 161(25.3)			
	2 = 150 (23.5)			
	3 = 165 (25.9)			
3 categories variable, 0 = none, 1 = low (<1/wk) & 2 = medium (≥1/wk)				
Meat ³	0 = 306 (48.0)	0.86	0.69, 1.06	0.17
	1 = 165 (25.9)			
	2 = 166 (26.1)			
Continuous variable, square root transformed and z-standardised; units = SD				
Milk & dairy products ¹	785 (100.0)	-0.007	-0.12, 0.10	0.90
Binary variable, 0 = none* & 1 = any				
Coffee ²	0 = 332 (52.1)	1	-	-
	1 = 305 (47.8)	1.01	0.80, 1.26	0.91
Continuous variable, square root transformed and z-standardised; units = SD				
Fried & fast food ¹	785 (100.0)	0.05	-0.06, 0.16	0.36
Continuous variable, square root transformed and z-standardised; units = SD				

Table 4.10: Regression analysis of physical activity as a predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Walking per week (in minutes) (no walking/week = 0, Between 1 & 150 minutes/ week = 1, >150 minutes/week =2)		
		β^1 / Odds ratio ^{2,3}	95% CI	p
Added sugar, SSB & high sugar products ¹	785 (100.0)	0.09	-0.01, 0.21	0.09
Binary variable, 0 = none* & 1 = any				
Nutrient enriched powders ²	0 = 462 (72.5) 1 = 175 (27.5)	1 1.32	- 1.03, 1.69	- 0.03
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium ($>1-3$ /wk) & 4 = high (>3 /wk)				
High salt products ³	0 = 146 (22.9) 1 = 127 (19.9) 2 = 124 (19.5) 3 = 240 (37.7)	1.19	0.97, 1.46	0.08
3 categories variable, 0 = low (<1 /wk), 1 = medium ($\geq 1-4$ /wk) & 2 = high (>4 /wk)				
Visible fat ³	0 = 349 (54.8) 1 = 151 (23.7) 2 = 137 (21.5)	0.97	0.78, 1.20	0.71

*Red text indicates reference group.

¹ Food groups in white=continuous variables; ² Food groups shaded in grey=binary variables;

³ Food groups shaded in blue=ordinal categorical variables.

Table 4.11: Regression analysis of T2DM family history as predictor of frequency of intake of food groups (N=785)**

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2, 3)}	Median (IQR) intakes of food groups No=N Yes=Y	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2, 3}	Predictor: Known T2DM family history among first degree relatives**: 0 = No, 1 = Yes		
			β ¹ / Odds ratio ^{2, 3}	95% CI	p
Continuous variable, z-standardised; units = SD					
Milled cereals & products ¹	N = 37.5 (30.3, 45.7) Y = 37.7 (30.1, 44.0)	785 (100.0)	-0.09	-0.24, 0.06	0.25
Binary variable, 0 = none* & 1 = any					
Wholegrain cereals ²	N = 6.0 (0.7, 8.0) Y = 3.0 (0.7, 7.5)	0=112 (14.3) 1=673 (85.7)	1 1.07	- 0.70, 1.66	- 0.74
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Pulse & lentil preparations ¹	N = 4.0 (2.2, 7.0) Y = 4.0 (2.5, 7.0)	785 (100.0)	0.05	-0.09, 0.20	0.49
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Salads & raw vegetables ¹	N = 3.0 (1.0, 6.2) Y = 3.0 (1.2, 6.4)	785 (100.0)	0.03	-0.12, 0.18	0.73
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Cooked vegetables ¹	N= 9.0 (6.0, 13.7) Y= 9.5 (6.2, 14.0)	785 (100.0)	-0.01	-0.16, 0.14	0.94
Binary variable, 0 = low (≤ 1 / week) & 1 = high (>1 / week)					
Potato containing dishes ²	N = 2.0 (1.1, 3.8) Y = 2.2 (1.2, 3.5)	0=185 (23.6) 1=600 (76.4)	1 1.11	- 0.78, 1.58	- 0.55
Binary variable, 0 = low (<1 / week)* & high (1 = >1 / week)					

Table 4.11: Regression analysis of T2DM family history** as predictor of frequency of intake of food groups (N=785)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups No=N Yes=Y	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Known T2DM family history among first degree relatives**: 0 = No, 1 = Yes		
			β^1 / Odds ratio ^{2,3}	95% CI	p
Potato palya ²	N = 0.7 (0.2, 1.0) Y = 0.7 (0.2, 1.0)	0=407 (51.8) 1=378 (48.2)	1 0.97	- 0.72, 1.31	- 0.87
Continuous variable, square root transformed and z-standardised; units = SD					
Cooked Green leafy vegetables ¹	N= 3.0 (2.0, 4.5) Y= 3.0 (2.0, 4.5)	785 (100.0)	0.06	-0.08, 0.21	0.43
Continuous variable, square root transformed and z-standardised; units = SD					
Fresh fruit, dried fruit & fruit juices ¹	N=24.5 (15.2, 36.8) Y=23.2 (15.2, 37.7)	785 (100.0)	-0.04	-0.19, 0.11	0.59
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Nuts & seeds ¹	N=5.0 (2.2, 11.1) Y=4.0 (2.0, 9.0)	785 (100.0)	-0.20	-0.35, 0.05	0.008
3 categories variable, 0 = none, 1 = low (<1/wk) & 2 = high ($\geq 1 - 3$ /wk)					
Fish & seafood ³	N=0.0 (0.0, 0.5) Y=0.0 (0.0, 0.5)	0=473 (60.3) 1=178 (22.6) 2=134 (17.1)	0.82	0.61, 1.11	0.20
3 categories variable, 0 = low (≤ 1 /wk), 1 = medium (>1 - 3/wk) & 2 = high (> 3/wk)					
Egg and egg preparations ³	N=2.0 (0.5, 4.0) Y=1.7 (0.5, 3.2)	0=302 (38.5) 1=256 (32.6) 2=227 (28.9)	0.92	0.69, 1.21	0.60
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium (>1-2/wk) & 3 = high (>2/ wk)					
Poultry ³	N=1.5 (0.0, 2.5) Y=1.1 (0.2, 2.0)	0=185 (23.6) 1=195 (24.8) 2=191 (24.3) 3=214 (27.3)	0.82	0.62, 1.07	0.14
3 categories variable, 0 = none, 1 = low (<1/wk), 2 = medium (≥ 1 /wk)					
Meat ³	N= 0.2 (0.0, 1.0) Y= 0.2 (0.0, 1.0)	0=367 (46.8) 1=200 (25.5) 2=218 (27.7)	0.90	0.83, 1.47	0.47
Continuous variable, square root transformed and z-standardised; units = SD					
Milk & dairy products ¹	N=19.5 (11.7, 27.7) Y=18.5 (13.1, 26.0)	785 (100.0)	0.02	-0.14, 0.17	0.84
Binary variable, 0 = none* & 1 = any					
Coffee ²	N=0.0 (0.0, 7.0) Y=0.0 (0.0, 7.0)	0=422 (53.8) 1=363 (46.2)	1 0.85	- 0.63, 1.15	- 0.29
Continuous variable, square root transformed and z-standardised; units = SD					
Fried & fast food ¹	N=6.2 (3.5, 10.5) Y=6.7 (3.5, 11.2)	785 (100.0)	0.01	-0.14, 0.16	0.91
Continuous variable, square root transformed and z-standardised; units = SD					
Added sugar, SSB & high sugar products ¹	0=19.5 (11.7, 30.1) 1=20.0 (12.5, 27.1)	785 (100.0)	0.006	-0.14, 0.16	0.93
Binary variable, 0 = none* & 1 = any					
Nutrient enriched beverage supplements ²	N=0.0 (0.0, 1.0) Y=0.0 (0.0, 1.0)	0=568 (72.4) 1=217 (27.6)	1 0.79	- 0.57, 1.09	- 0.16
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium (>1-3/wk) & 4 = high (> 3/ wk)					
High salt products ³	N=1.7 (0.2, 7.0) Y=2.0 (0.2, 7.0)	0=174 (22.2) 1=154 (19.6) 2=153 (19.5) 3=304 (38.7)	1.19	0.91, 1.57	0.19

Table 4.11: Regression analysis of T2DM family history as predictor of frequency of intake of food groups (N=785)**

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2, 3)}	Median (IQR) intakes of food groups No=N Yes=Y	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2, 3}	Predictor: Known T2DM family history among first degree relatives**: 0 = No, 1 = Yes		
			β ¹ / Odds ratio ^{2, 3}	95% CI	p
			3 categories variable, 0 = None and low (<1/wk), 1 = medium (≥ 1 - 4/wk) & 2 = high (>4/wk)		
Visible fat ³	N=1.0 (0.0, 3.0) Y=0.2 (0.0, 3.0)	0=417 (53.1) 1=196 (25.0) 2=172 (21.9)	0.79	0.59, 1.06	0.11

***Red text indicates reference group.** **First degree relatives include father, mother or siblings.

¹ Food groups in white=continuous variables; ² Food groups shaded in grey=binary variables; ³ Food groups shaded in blue=ordinal categorical variables.

Table 4.12: Regression analysis of PCOS as a predictor of frequency of intake of food groups (N=784*)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups N=No Y=Yes	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: PCOS diagnosis (0 = No, 1 = Yes)		
			β^1 / Odds ratio ^{2,3}	95% CI	p
Continuous variable, z-standardised; units = SD					
Milled cereals & products ¹	N=38.0 (30.8, 45.5) Y=35.2 (28.5, 43.2)	784 (100.0)	-0.26	-0.49, -0.03	0.02
Binary variable, 0 = none* & 1 = any					
Wholegrain cereals ²	N = 4.5 (1.0, 7.7) Y = 2.7 (0.5, 9.0)	0 =111(14.2) 1=673 (85.8)	1 1.09	- 0.56, 2.12	- 0.80
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Pulse & lentil preparations ¹	N = 4.0 (2.2, 6.2) Y = 5.0 (3.0, 9.0)	784 (100.0)	0.37	0.14, 0.59	0.002
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Salads & raw vegetables ¹	N = 3.0 (1.2, 6.0) Y = 4.0 (1.5, 8.0)	784 (100.0)	0.23	0.007, 0.46	0.04
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Cooked vegetables ¹	N = 9.2 (6.0, 13.7) Y= 10.0 (7.0, 14.2)	784 (100.0)	0.12	-0.10, 0.35	0.29
Binary variable, 0 = low (≤ 1 /wk)* & 1 = high (>1/wk)					
Potato containing dishes ²	N = 2.2 (1.2, 3.7) Y = 2.0 (1.0, 3.0)	0=185 (23.6) 1=599 (76.4)	1 0.78	- 0.47, 1.31	- 0.35
Binary variable, 0 = low (<1/wk) & high (1 = ≥ 1 /wk)					
Potato palya ²	N = 0.7 (0.2, 1.0) Y = 0.5 (0.0, 1.0)	0=407 (51.9) 1=377 (48.1)	1 0.57	- 0.36, 0.93	- 0.02
Continuous variable, square root transformed and z-standardised; units = SD					
Cooked Green leafy vegetables ¹	N = 3.0 (2.0, 4.7) Y = 2.5 (1.5, 4.0)	784 (100.0)	-0.33	-0.55, -0.10	0.005
Continuous variable, square root transformed and z-standardised; units = SD					
Fresh fruit, dried fruit & fruit juices ¹	N = 23.2 (15.0, 35.7) Y = 28.5 (18.2, 45.7)	784 (100.0)	0.37	0.14, 0.59	0.001
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Nuts & seeds ¹	N = 4.2 (2.0, 9.3)	784 (100.0)	0.24	0.01, 0.47	0.03

Table 4.12: Regression analysis of PCOS as a predictor of frequency of intake of food groups (N=784*)

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups N=No Y=Yes	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: PCOS diagnosis (0 = No, 1 = Yes)		
			β^1 / Odds ratio ^{2,3}	95% CI	p
Y = 6.0 (2.0, 16.0)					
3 categories variable, 0 = none, 1 = low (<1/wk) & 2 = high ($\geq 1 - 3$ /wk)					
Fish & seafood ³	N = 0.0 (0.0, 0.5) Y = 0.0 (0.0, 1.0)	0=473 (60.3) 1=177 (22.6) 2=134 (17.1)	1.27	0.82, 1.98	0.28
3 categories variable, 0 = low (≤ 1 /wk), 1 = medium (>1 - 3/wk) & 2 = high (> 3/wk)					
Egg and egg preparations ³	N = 2.0 (0.5, 3.5) Y = 1.5 (0.0, 4.0)	0=302 (38.5) 1=256 (32.7) 2=226 (28.8)	0.93	0.61, 1.41	0.72
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium (>1-2/wk) & 3 = high (> 2/wk)					
Poultry ³	N = 1.2 (0.2, 2.2) Y = 0.7 (0.0, 2.2)	0=185 (23.6) 1=195 (24.9) 2=191 (24.3) 3=213 (27.2)	0.65	0.43, 0.98	0.04
3 categories variable, 0 = none, 1 = low (<1/wk) & 2 = medium (≥ 1 /wk)					
Meat ³	N = 0.2 (0.0, 1.0) Y = 0.0 (0.0, 1.2)	0=367 (46.8) 1=200 (25.5) 2=217 (27.7)	0.94	0.62, 1.44	0.79
Continuous variable, square root transformed and z-standardised; units = SD					
Milk & dairy products ¹	N = 19.0 (13.0, 26.5) Y = 17.2 (11.5, 26.2)	784 (100.0)	-0.12	-0.35, 0.11	0.29
Binary variable, 0 = none* & 1 = any					
Coffee ²	N = 0.0 (0.0, 7.0) Y = 0.0 (0.0, 3.0)	0=422 (53.8) 1=362 (46.2)	1 0.88	- 0.56, 1.39	- 0.59
Continuous variable, square root transformed and z-standardised; units = SD					
Fried & fast food ¹	N = 6.7 (3.5, 11.2) Y = 6.0 (3.5, 10.2)	784 (100.0)	-0.08	-0.30, 0.14	0.48
Continuous variable, square root transformed and z-standardised; units = SD					
Added , SSB and high sugar products ¹	N = 20.0 (12.5, 27.8) Y = 18.5 (10.7, 27.5)	784 (100.0)	-0.10	-0.33, 0.12	0.36
Binary variable, 0 = none* & 1 = any					
Nutrient enriched beverage supplements ²	N = 0.0 (0.0, 0.5) Y = 0.0 (0.0, 4.0)	0=567 (72.3) 1=217 (27.7)	1 1.96	- 1.23, 3.13	- 0.005
4 categories variable, 0 = none, 1 = low (≤ 1 /wk), 2 = medium (>1-3/wk) & 4 = high (> 3/wk)					
High salt products ³	N = 2.0 (0.2, 7.0) Y = 2.0 (0.2, 6.0)	0=173 (22.1) 1=154 (19.6) 2=153 (19.5) 3=304 (38.8)	1.13	0.75, 1.71	0.55
3 categories variable, 0 = low (<1/wk), 1 = medium ($\geq 1 - 4$ /wk) & 2 = high (>4/wk)					
Visible fat ³	N = 0.5 (0.0, 3.0) Y = 0.5 (0.0, 3.0)	0=416 (53.1) 1=196 (25.0) 2=172 (21.9)	1.08	0.70, 1.67	0.71

*PCOS data missing for 1 woman. *Red text indicates reference group.

¹ Food groups in white=continuous variables; ² Food groups shaded in grey=binary variables;³ Food groups shaded in blue=ordinal categorical variables.

Table 4.13: Regression analysis of gravidity as a predictor of frequency of intake of food groups (N=785).

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups P=Primigravid M=Multigravid	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Gravidity (Primigravid = 0, Multigravid = 1)		
			β ¹ / Odds ratio ^{2,3}	95% CI	p
Continuous variable, z-standardised; units = SD					
Milled cereals & products ¹	P = 36.7 (29.8, 44.5) M = 38.0 (31.3, 45.6)	785 (100.0)	0.11	-0.03, 0.25	0.12
Binary variable, 0 = none & 1 = any					
Wholegrain cereals ²	P = 4.0 (0.5, 7.7) M = 4.2 (1.0, 8.0)	112 (14.3) 673 (85.7)	1 1.12	- 0.75, 1.68	- 0.12
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Pulse & lentil preparations ¹	P = 4.0 (2.2, 6.2) M = 4.0 (2.5, 7.5)	785 (100.0)	0.09	-0.05, 0.23	0.21
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Salads & raw vegetables ¹	P = 3.0 (1.2, 6.0) M = 3.0 (1.2, 7.0)	785 (100.0)	0.07	-0.07, 0.21	0.34
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Cooked vegetables ¹	P = 8.7 (5.7, 13.5) M = 9.7 (7.0, 14.0)	785 (100.0)	0.19	0.05, 0.33	0.007
Binary variable, 0 = low (<1/wk)* & 1 = high (>1/wk)					
Potato containing dishes ²	P = 2.2 (1.2, 3.7) M = 2.0 (1.2, 3.5)	0=185 (23.6) 1=600 (76.4)	1 0.95	- 0.68, 1.32	- 0.76
Binary variable, 0 = low (<1/wk)* & high (1 = ≥1/wk)					
Potato palya ²	P = 0.7 (0.2, 1.0) M = 1.0 (0.2, 1.0)	0=407 (51.8) 1=378 (48.2)	1 1.25	- 0.94, 1.65	- 0.12
Continuous variable, square root transformed and z-standardised; units = SD					
Cooked Green leafy vegetables ¹	P = 2.7 (2.0, 4.2) M = 3.2 (2.0, 4.8)	785 (100.0)	0.14	-0.002, 0.28	0.05
Continuous variable, square root transformed and z-standardised; units = SD					
Fresh fruit, dried fruit & fruit juices ¹	P = 22.0 (14.0, 35.2) M = 24.5 (16.5, 39.2)	785 (100.0)	0.19	0.04, 0.32	0.01
Continuous variable, log (x+1) transformed and z-standardised; units = SD					
Nuts & seeds ¹ :	P = 4.0 (2.0, 9.0) M = 5.0 (2.2, 11.0)	785 (100.0)	0.16	0.02, 0.30	0.02
3 categories variable, 0 = none, 1 = low (<1/wk) & 2 = high (≥1 - 3/wk)					
Fish & seafood ³	P = 0.0 (0.0, 0.2) M = 0.0 (0.0, 0.5)	0=473 (60.3) 1=178 (22.6) 2=134 (17.1)	1.27	0.95, 1.67	0.09
3 categories variable, 0 = low (<1/wk), 1 = medium (>1 - 3/wk) & 2 = high (>3/wk)					
Egg and egg preparations ³	P = 1.5 (0.2, 3.2) M = 2.0 (0.7, 4.0)	0=302 (38.5) 1=256 (32.6) 2=227 (28.9)	1.44	1.10, 1.86	0.006
4 categories variable, 0 = none, 1 = low (≤ 1/wk), 2 = medium (>1-2/ week) & 3 = high (> 2/wk)					
Poultry ³	P = 1.0 (0.0, 2.2) M = 1.2 (0.2, 2.2)	0=185 (23.6) 1=195 (24.8) 2=191 (24.3) 3=214 (27.3)	1.23	0.95, 1.58	0.10

Table 4.13: Regression analysis of gravidity as a predictor of frequency of intake of food groups (N=785).

Outcome: Weekly frequency of intake of food groups (z-scores ¹ and categorical intakes ^{2,3})	Median (IQR) intakes of food groups P=Primigravid M=Multigravid	Number in sample Total N (%) ¹ N (%) in each outcome category ^{2,3}	Predictor: Gravidity (Primigravid = 0, Multigravid = 1)		
			β ¹ / Odds ratio ^{2,3}	95% CI	p
3 categories variable, 0 = none, 1 = low (<1/wk), 2 = medium ($\geq$ 1/wk)					
Meat ³	P = 0.0 (0.0, 0.7) M = 0.2 (0.0, 1.2)	0=367 (46.8) 1=200 (25.5) 2=218 (27.7)	1.59	1.21, 2.06	0.001
Continuous variable, square root transformed and z-standardised; units = SD					
Milk & dairy products ¹	P = 18.2 (11.5, 26.5) M = 19.5 (14.0, 26.5)	785 (100.0)	0.08	-0.05, 0.22	0.24
Binary variable, 0 = none* & 1 = any					
Coffee ²	P = 0.0 (0.0, 7.0) M = 0.0 (0.0, 7.0)	0=422 (53.8) 1=363 (46.2)	1 1.30	- 0.98, 1.72	- 0.06
Continuous variable, square root transformed and z-standardised; units = SD					
Fried & fast food ¹	P = 7.0 (3.5, 11.5) M = 6.1 (3.5, 10.7)	785 (100.0)	-0.06	-0.20, 0.07	0.39
Continuous variable, square root transformed and z-standardised; units = SD					
Added sugar, SSB & high sugar products ¹	P = 18.2 (11.2, 26.7) M = 21.6 (13.9, 29.5)	785 (100.0)	0.12	-0.02, 0.26	0.09
Binary variable, 0 = none* & 1 = any					
Nutrient enriched beverage supplements ²	P = 0.0 (0.0, 2.0) M = 0.0 (0.0, 0.0)	0=568 (72.4) 1=217 (27.6)	1 0.66	- 0.47, 0.90	- 0.009
4 categories variable, 0 = none, 1 = low ($\leq$ 1/wk), 2 = medium (>1-3/wk) & 4 = high (>3/ wk)					
High salt products ³	P = 2.0 (0.2, 7.0) M = 2.0 (0.2, 7.0)	0=174 (22.2) 1=154 (19.6) 2=153 (19.5) 3=304 (38.7)	1.12	0.87, 1.44	0.37
3 categories variable, 0 = None and low (<1/wk), 1 = medium ($\geq$ 1- 4/wk) & 2 = high (>4/ wk)					
Visible fat ³	P = 0.5 (0.0, 3.0) M = 0.5 (0.0, 3.0)	0=417 (53.1) 1=196 (25.0) 2=172 (21.9)	0.97	0.74, 1.27	0.84

*Red text indicates reference group.

¹ Food groups in white=continuous variables; ² Food groups shaded in grey=binary variables;³ Food groups shaded in blue=ordinal categorical variables.

APPENDIX Q

GLOSSARY OF INDIAN FOODS IN THE BANGLES FFQ (parts adapted and modified from Sudha et al., 2016)

Buttermilk	A popular south Indian savoury drink prepared from whipped curd diluted with water and salt. Asafoetida and curry leaves are optional.
Horlicks, complan, boost, bournvita, Pro PL, baby & me, Pristine Balance PL, Protovic DF, Nutriright Mom, GRD Smart	Types of nutrient enriched, sweetened supplement powders consumed with mostly milk or at times hot water.
Hersheys syrup / choco syrup	Concentrated sweetened chocolate flavoured syrup for milk and used with milk and on desserts.
Badam milk	Traditional milk drink prepared by boiling milk with ground almonds, sugar, saffron and cardamom.
Sugarcane juice	Sugarcane juice is the liquid extracted from pressed sugarcane.
Squashes / syrups (tang/kisan/ rasna/ roohafza/lemonade)	Concentrated flavoured sweetened syrups made by diluting water.
Red rice	Kerala Matta rice is an indigenous variety of rice grown in Palakkad district of Kerala, India. It is different from brown rice. It is popular in Kerala and coastal Karnataka in India.
Brown rice	Unpolished variety of rice with outer layer intact.
Rice with dal / sambhar	A staple dish in Karnataka where rice mixed with sambhar (cooked with red gram dal, vegetables, tamarind pulp and spices).
Rice with glv	Also known as green pulao or green leafy vegetable is prepared with rice cooked with green leafy vegetables and spices.
Spice Seasoned/ flavoured rice (tamarind / lemon / ghee / tomato)	Spice seasoned rice are varieties of rice consumed for breakfast or lunch usually. It is prepared by seasoning cooked rice with oil, spices and tamarind pulp/lemon juice/tomatoes.
Vegetable bath or pulao / bisi bele bath / veg khichdi	Pulao or vegetable baath is prepared with buttered long grain or aromatic basmati rice cooked with vegetables, spices, nuts and flavours. Bisibelebaath is a popular main course dish in the southern state of Karnataka. It is prepared by cooking rice, red gram dal, vegetables and tamarind pulp with ground spicy masala including dry coconut/ roasted coconut. Served

	hot with ghee. Khichdi is prepared by pressure cooking rice with green gram dhal, red gram dhal, vegetables, spices and ghee.
Curd rice	A traditional rice dish made by mixing curds, cooked rice, onion and spices.
Rice vermicelli / avalakki/ puffed rice (mandakki)	Rice vermicelli also known as semiya is similar to Idiyappam. It is prepared by sautéing with onion, spices and lemon juice and sometimes coconut or other vegetables. Puffed rice is eaten as a breakfast or evening snack. It is softened with water and cooked with oil, onion, spices and this dish is called 'mandakki' in Karnataka.
Idly	A traditional breakfast popular staple food in southern Indian states, in recent times prepared from ready batters in urban areas. Idly is a spongy steamed rice cake made from a fermented batter of rice and black gram dal in a desired proportion.
Plain dosa	Dosa is made from fermented batter of parboiled rice and split black gram and cooked in shallow pan called tava with oil or without oil in non-stick pan. There is a filling with a spicy potato stir-fry inside the masala dosa. A traditional bread rice roti is made from rice flour, warm water, spices and sometimes greens.
Masala dosa	
Rice roti	
Rice puttu/ kadabu	Puttu is a popular breakfast dish in Kerala and Tamil Nadu. It is a steamed rice flour cake prepared using a specially designed puttu mould and served with grated coconut, sugar or without sugar and ripe banana at times.
Chapati	Dough made of wheat flour, salt, water rested for 30 minutes and then rolled into flat breads and cooked on both sides with oil/ ghee in tava.
Poori	Wheat flour (refined or whole wheat) kneaded hard or tightly is rolled into small circlets and deep fried in oil.
Parantha	A popular traditional main course in Punjab state popular all over India. Soft dough prepared from whole wheat flour is rolled into chapathi and stuffed with cooked vegetables such as methi leaves, cauliflower, potato, onion and shallow fried on griddle pan with oil/ ghee/ butter.
Sweet bun / kara bun	Kara bun is a type of bun made with spices such as fennel, chillies, onion etc.
Uppuma	Uppuma is a traditional south Indian breakfast item, prepared by stir frying followed by boiling semolina/ sago in water with the addition of onion, salt and spices.
Broken wheat / dalia	Broken wheat is made by milling whole raw wheat grains coarsely. It is boiled with water like rice and eaten with lentil and vegetable side dishes.
Spagetti / noodles	A Chinese cuisine staple, popular in several parts of India. It is prepared by stir frying the noodles with vegetables such as carrot, capsicum, cabbage with sauce and spices.

Ragi roti	A traditional bread made from ragi, onion and spices or other millets such as bajra, jowar etc.
Ragi ball	A traditional semi-solid gruel prepared from finger millet or ragi are commonly consumed as breakfast choices especially in Karnataka known locally as 'ragi mudde' in urban and mainly in rural areas. Ragi is boiled in water with salt to desired consistency and made into balls.
Ragi dosa	A type of pancake made with ragi flour, buttermilk and spices on a shallow pan.
Ragi Malt / Multigrain Malt / Ganji	Porridge of a thin consistency consumed for breakfast especially in rural areas. Ragi flour is boiled with water, milk (optional) and salt/sugar. In some parts of India buttermilk is also added.
Ragi vermicelli	A snack or breakfast dish made with vermicelli made out of ragi that is boiled and cooked with onion and spices.
Urad vada	A popular snack in most parts of India, It is prepared with coarsely/ finely ground paste of split black gram and mixed with onion, coriander leaves, ginger, black pepper grits, asafoetida and hand pressed into circular shape with a hole in the centre for even cooking and then deep fried in oil. Vadas are also made sometimes with Bengal gram dal, onions, spices and deep fried.
Chilas / adai / pesarattu	Traditional breakfast/ dinner main dish from the state of Tamil Nadu. It is a thick type of dosa (pancake) made out of coarsely ground batter of rice and pulses and is cooked on a hot tava/ griddle with oil.
Legume based dhal	A side dish prepared by boiling whole legumes like Bengal gram, rajmah, cowpeas, chickpeas with salt and seasoned with spices and onion.
Split dal based dhal	A side dish prepared by boiling split dhal from whole legumes like bengal gram dhal, moong dhal, red gram dhal etc. with salt and seasoned with spices and onion.
Potato palya Carrot palya	Palya is a term for vegetable side dishes in Kannada where vegetables are stir fried with spices and grated coconut.
Mixed veg sambhar Glv / soppu sambhar	Sambhar is a traditional side dish eaten often with rice and sometimes with idly. Made out of red gram dhal, tomatoes, onion, vegetables or green leafy vegetables alone - cooked in tamarind pulp along with spices.
Multi vegetable saagu	Saagu is a meal accompaniment with rice, chapathi, parantha etc. Many vegetables such as carrot, green peas, potato etc. are cooked with spices and coconut paste/ coconut milk to a thick consistency.
Rasam	In South Indian households rasam commonly refers to soup prepared with sweet-sour stock made from tamarind, along with tomato and lentil, added spices and garnish.
Kosambari	Kosambari is a typical south Indian salad made from pulses (split legumes) and seasoned with mustard seeds.

Chicken biriyani	A special occasion rice dish made with edible portions of chicken cooked with ground spices for flavouring and tossed with stir fried aromatic basmati rice.
Chicken fry	Edible portions of chicken cooked with spices and shallow fried or deep fried in oil or pan or kadai.
Chicken curry	Edible portions of chicken sautéed with ginger, garlic paste, spices and coconut or without coconut cooked in water to a thick consistency or gravy.
Fish fry	Edible portions of fish cooked with spices and shallow fried or deep fried in oil or pan or kadai.
Fish curry	Edible portions of fish sautéed with ginger, garlic paste, spices and coconut or without coconut cooked in water to a thick consistency or gravy or steamed and then fried.
Lamb, beef, pork- fry	Edible portions of mutton cooked with spices and shallow fried or deep fried in oil or pan or kadai.
Lamb, beef, pork - cutlet	Cutlet is a deep fried or shallow fried snack prepared by cooking meat by itself or with vegetables, spices, made into balls, flattened to desired shapes dipped into egg mix and coated with bread crumbs sometimes.
Lamb, beef, pork - curry	Edible portions of mutton sautéed with ginger, garlic paste, spices and coconut or without coconut cooked in water to a thick consistency or gravy or steamed and then fried.
Keema curry	A traditional dish of the Indian subcontinent, typically minced-lamb curry with peas or potatoes and spices.
Mutton biriyani	A special occasion rice dish made with edible portions of mutton cooked with ground spices for flavouring and tossed with stir fried aromatic basmati rice.
Egg biriyani	A special occasion rice dish made with edible portions of egg cooked with ground spices for flavouring and tossed with stir fried aromatic basmati rice.
Egg burchi, curry	It is a side dish eaten with chapathi, rice or western style breads. Egg burchi is made with egg scrambled in oil, onion, chillies and spices or a curry is made with spices and onion paste with boiled eggs cooked in the gravy.
Pickle (lemon / mango)	A preserved food popular as accompaniments in India. It is made of mango / lemon and garlic, tomato, chillies, mixed vegetables, prawn, fish and cooked with spices, salt and oil.
Coconut chutney	Chutney is a very common condiment used with Indian foods made of coconut, groundnut, mango, tomato or mint or any other vegetable, cooked and ground with salt and spices.
Groundnut chutney	
Other Chutney and Powders	Chutney powders are preserved chutney powders made from dry ingredients such as groundnut, lentils and spices.
Jaggery	Jaggery is a traditional non-centrifugal cane sugar consumed in some countries in Asia and the Americas. It is a concentrated product of cane juice and often date or palm sap (see: palm sugar) without separation of the molasses and

	crystals, and can vary from golden brown to dark brown in colour. It contains up to 50% sucrose, up to 20% invert sugars, and up to 20% moisture, with the remainder made up of other insoluble matter, such as wood ash, proteins, and bagasse fibres
Papad/ sandige (home fried)	Thin crispy Indian accompaniment made out of a dhal dough usually black gram dhal/ green gram dhal, rice and cumin seeds, rolled into a thin flatbread, shade sun dried and either roasted or deep fried in oil.
Namkeen/mixtures/savouries	It is a Bengal gram dhal flour based deep fried snack/ savoury/ namkeen commonly eaten in India.
Chakli/murukku/kod bale	Savoury snacks made from soft dough prepared with rice flour, split Bengal ram flour, cumin seeds, salt, butter and water. The dough is places in a mould, pressed and deep fried in oil into circular extruded shapes.
Pakoda/bonda/bhajji /samosa	Bonda / Pakoda/ bhajji are spicy fried snack popular in the southern states of India. A thick batter of besan (Bengal gram dal) is mixed with onion and green chillies, made into balls and deep fried in oil. Samosa is a popular snack in India, especially in North. Dough made from refined wheat flour is folded into triangular shape wrap and stuffed with cooked mixture of potato, peas, carrot, onion and spices and deep fried in oil.
Babycorn / gobi manchurian	Gobi (cauliflower) manchurian is the result of the adaptation of Chinese cooking and seasoning techniques to suit Indian tastes. It has cauliflower fritters in comparatively dry sauce like texture and is typically served and enjoyed as a snack or starter with tomato ketchup as dipping sauce.
Boiled / roasted corn	Boiled sweetcorn topped with butter, salt or other spice flavours.
Puff	Puff is eaten as a snack. The primary ingredient is refined wheat flour and hydrogenated fat (vanaspathi) which are blended into a soft dough and folded into layers and further rolled and baked with cooked vegetables/ meat/ egg / chicken.
Kesaribaath	Kesaribaath is a sweet made from roasted wheat grits and cooked with sugar, water and flavoured with ghee, cardamom or saffron and cashew nuts.
Obbattu/holige/boli/ bobatlu/puranpoli	A popular dish in Maharashtra, Gujrat, Karnataka, Andhra Pradesh and Tamil Nadu. Soft dough prepared with refined wheat flour rolled into a chapathi and stuffed with a mixture of Bengal ram dhal, sugar/ jiggery, nutmeg, cardamom, coconut and shallow fried with ghee.
Barfi /pedha	Pedha is a milk based sweet where milk is reduced with sugar and sugar and cooked at a simmering temperature till it separates from the sides of the pan. Addition of ghee and other flavourings like saffron, cardamom and flavours are optional. Barfi is an Indian sweet made with ground coconut paste/ split Bengal gram flour, cooked with milk and sugar (or

	jaggery) and cooked till it separates from the sides of the pan, then spread on plate and cut into desired shapes.
Gulab jamoon, jalebi. jangir	Gulab jamoon: Milk based popular Indian sweet prepared with milk khoa and refined wheat flour to form a soft dough and made into small balls. It is then deep fried in oil or ghee and dipped in a sugar syrup. Jalebi: It is made with black gram dhal batter squeezed through cone (similar to icing cone) nozzle into circular shapes and fried in oil. Dipped in sugar syrup and served.
Chikki	Chikki is a peanut/ groundnut based sweet popularly called chikki. It is made with groundnut, sesame seeds or any crushed nuts cooked in jaggery syrup rolled into balls or flat squares.
Laddoo, mysore pak	Mysore pak is Bengal gram flour ghee roasted and blended with hot sugar syrup and ghee and cooked till it leaves the sides of the pan. The mixture is poured onto a greased plate and cooled. Later sliced into rectangular pieces. Ladoo is a traditional sweet where batter of Bengal gram dhal flour is deep fried in oil using perforated ladle and this cooked boondhi is further mixed with sugar syrup, ghee, roasted cashew nuts and cardamom. This mixture is hand pressed into balls of desired sizes.
Halwa (dumroot/carrot)	A popular Indian sweet made from wheat flour, grated carrot, bottle gourd or semolina, cooked with sugar, ghee and water/ milk to a thick consistency.
Kheer/Payasam	Roasted vermicelli/ semolina/ green gram dhal/ carrot is cooked with milk and sugar/ jaggery and flavoured with ghee, cardamom and cashew nuts.
Bengali sweets	Bengali sweets are all made of reducing full cream milk into chenna or cottage cheese and mixing with saffron, sugar in different combinations. They are popular in all parts of India.
Chats: pani puri, bhel puri etc.	It is a north Indian savoury snack but popular all over India, especially in urban areas. Bhel puri is a mixture of puffed rice, sev (fried thins made of besan flour), salad vegetables (tomato, potato, onion and cucumber) and crisp puris tossed with a tangy sweet and sour chutney and green chutney. Pani puri is a hollow crisp puri made of semolina, refined flour, filled with tamarind juice, spice powders made of raw mango, cumin, coriander, black pepper, rock salt and chilli powder along with boiled mashed potato and chickpeas or green gram.
Raita (any vegetable raita)	Raita is an accompaniment for chapathi/roti/rice based dishes in North India. Curd mixed with salad vegetables like onion, cucumber, carrot, tomato and seasoned with spices.
Ghee on the plate/ table	Ghee is clarified butter made by melting butter and separating the fat from the solids.
Paneer curry(paneer butter masala/kadai paneer)	An accompaniment for roti/ naan/ plain rice in North India. It is prepared with boiled and mashed green leafy vegetables or

onion and tomato and cooked with paneer (Indian cottage cheese, garlic, ginger and other spices to a thick consistency.

Paneer tikka

Paneer tikka is an Indian dish made from chunks of paneer marinated in spices and grilled in a tandoor or shallow pan.

APPENDIX R

Table 7.1: 55 food groups, their components and modifications to construct the 68 food groups

Food groups	Food group components	Change in the new 68 food groups
Commonly consumed beverages	Tea	Grouped together as one group
	Coffee	
Milk	Normal cows milk (as plain milk / Horlicks etc.)	Retained
	Skimmed cows milk (as plain milk / Horlicks etc.)	
Fermented dairy products	Buttermilk	Retained
	Raitha (any vegetable raita)	
Flavoured sweetened nutrient supplements	Horlicks, Complan, Boost, Bournvita	Retained
	Pro PL	
	Baby and me	
	Pristine balance PL	
	Nutri right mom	
	GRD Smart	
	Protovic DF	Retained
Flavoured sweetened beverages	Glucon d powder	
	Hersheys syrup / choco syrup	
	Badam milk	
	Sugarcane juice	
	Packaged fruit juice(real, tropicana etc.)	
	Coke/ pepsi / sprite / mirinda / fanta or other fizzy drink	
	Frooti / Maaza / Slice / Nimbooz / Appy fizz	
	Squashes / syrups (tang/kisan/ rasna/ roohafza/lemonade)	Retained
Therapeutic beverages	Electoral	
	Tender coconut water	Retained
Soups	Fresh vegetable soups	
	Rasam	
	Herbal drinks	
	Fresh non - veg soups	Retained
Fresh fruit juices	Fresh fruit juice specify fruit:	
Low calorie fruits	Apple	Not retained. All fruits combined with commonly consumed fruits kept separate such as apple, sweet lime, banana and pomegranate.
	Sweet lime	
	Guava	
	Pomegranate	
	Musk melon	
	Pear	
	Papaya	
High calorie fruits	Banana (pacche/robusta/ nendra - kerala type)	
	Banana (yelakki)	
	Sapota	
	Grapes (green)	Grouped separately
	Pineapple	
	Avocado	
Mixed fruit salad	Mixed fruit salad	Grouped separately
Dried fruits	Dates	

Food groups	Food group components	Change in the new 68 food groups
	Raisins	
	Figs	Grouped separately
	Prunes	
	Apricots	
Nuts and seeds + preparations	Almonds	Grouped separately
	Cashewnuts	Grouped separately
	Pistachios	
	Sunflower seeds	
	Pumpkin seeds	
	Flax seeds	
	Groundnuts	
	Walnuts	
	Chia seeds	
	Coconut chutney	Grouped separately
	Groundnut chutney	
	Chikki	Grouped with nuts
Polished rice preparations	Plain/boiled rice	Both separated as individual groups since both were commonly consumed and eaten in different combinations
	Colour / seasoned rice (tamarind / lemon / ghee / tomato)	
Unpolished rice	Red rice	Retained
	Brown rice	
Rice and dal preparations	Rice with dal / sambhar	Kept separate
	Vegetable bath / bisi bele bath / veg khichdi	Combined with colour rice
	Idly	Kept separate
Rice and greens preparations	Rice with glv specify glv:	Retained
Curd rice	Curd rice	Retained
Semolina/beaten rice and vegetable preparation	Rice vermicelli / avalakki/ puffed rice (mandakki)	Retained
	Uppuma	
Fried cereal and pulse preparations	Plain dosa	Dosas kept separate
	Masala dosa	
	Poori	
	Paratha	Poori and parantha combined
	Urad vada	Urad vada and chilas combined
	Chilas / adai / pesarattu	
Whole grain breads	Chapathi	Chapathi & broken wheat kept separate
	Sliced brown bread	Moved into another group of western breads
	Broken wheat / dalia	
Refined cereal preparations	Rice roti	Combined as all are traditional rice dishes
	Rice puttu/kadabu	
	Sweet bun / kara bun	Separately grouped as western breads
	Sliced white bread	
	Pasta / macaroni	
	Spaghetti / noodles	
Ready to eat breakfast cereals	Wheat flakes	Retained
	Oat + milk	
	Oats + water	
	Muesli	
	All bran flakes	
	Corn flakes (plain)	
	Corn flakes (with dry fruit)	
Millet preparations	Ragi roti	Retained

Food groups	Food group components	Change in the new 68 food groups
	Ragi dosa	
	Ragi malt	
	Ragi vermicelli	
Ragi ball	Ragi ball	Retained
Whole and split pulse preparations	Legume based dhal (green gram / bengal gram/ channa/rajma)	Retained
	Split dal based dhal(moong/ toor/ masoor)	
	Mix veg sambhar	
	Kosambari	Except Kosambari separated as it is a traditional salad
Roots and tuber sides	Potato palya	Retained
	Carrot palya	
	Beetroot, radish, yam, tapioca palya	
Other vegetable sides	Ladysfinger palya	Retained
	Chow chow, pumpkin, gourds	
	Capsicum palya	
	Drumstick palya	
	Brinjal palya	
	Beans playa	
	Mushroom palya	
	Multi vegetable saagu	
Green leafy vegetable sides	Glv / soppu sambhar	Traditional GLV sides kept separate as a group.
	Glv / soppu palya	
	Cabbage / knol khol palya	Other GLV sides as a separate group.
	Cauliflower palya	
Raw vegetables	Cucumber (without skin)	Retained
	Tomato	
	Onion	
	Carrot	
	Radish	
	Runner beans	
Chicken preparations	Chicken biriyani	Grouped separately
	Chicken fry (roasted/grilled)	Grouped separately
	Chicken curry	
Fish preparations	Fish fry	Retained
	Fish curry	
	Fish cutlet	
	Dried fish / dried seafood	
	Prawn, crab, shellfish	
Red meat preparations	Lamb, beef, pork- fry	Retained
	Lamb, beef, pork - cutlet	
	Lamb, beef, pork - curry	
	Liver, brain, kidney	
	Keema curry	
	Ham / salami / bacon	
	Mutton biriyani	
Egg preparations	Egg - boiled (with yolk)	Grouped separately
	Egg biriyani	Grouped separately
	Egg - boiled (without yolk)	
	Egg burchi, curry	
	Omelette with yolk	
	Omelette without yolk	
High salt products	Pickle (lemon / mango)	Grouped as traditional condiments with chutneys.
	Papad/ sandige (home fried)	
	Chutney powders	
	Ketchup	

Food groups	Food group components	Change in the new 68 food groups
	Ready to make soups	Grouped separately as western condiments
High sugar additives	Jam	Retained
	Honey	
	Sugar in fruit juice	
	Sugar in tea	
	Sugar in coffee	
	Sugar in milk	
	Jaggery	Retained
Medium calories fried savoury snacks	Namkeen/mixtures/savouries	
	Chakli/murukku/kodbale	Retained
High calories fried savoury snacks	Pakoda/bonda/bhajji/samosa	
	Babycorn / gobi manchurian	
	Chips (potato/plantain)french fries	Retained
Puff pastry snacks	Puff	
Chocolates	Chocolate*specify brand:	Retained
	Toffee/ candy	
Cakes	Cake without cream	Retained
	Cake with cream / pastry	
Biscuits	Sweet biscuits (eg: parle g / glucose / tiger / marie / goodday)	Retained
	Salted biscuitseg: monaco / 50 - 50 / krackjack / maska chaska	
	Cream biscuitseg: dream cream, milky bite, jim jam, bourbon, britannia pure ma	
Cereal based sweet preparations	Kesaribaath	Retained, named as traditional homemade sweets with Kheer.
	Obbattu/ holige / boli/ bobatlu/ puranpoli	
Fried sweet preparations	Barfi /pedha	Retained, named as shop-bought Indian sweets.
	Gulab jamoon, jalebi. jangir	
	Laddoo, mysore pak	
	Halwa (dumroot/carrot)	Grouped with traditional homemade sweets.
Milk based sweet preparations	Kheer / payasam	
	Bengali sweets - rasgulla / rasmalai / chum chum / champakali/ malai sandwich	Merged with shop-bought Indian sweets.
	Pudding/custard/souffle/cheese cake	
Chats	Masala puri, pani puri, bhel puri etc.	Retained
Fast foods	Veg pizza	Retained
	Non veg pizza	
	Veg burger	
	Non veg burger	Retained
Curd/yogurt	Curd	
Butter and clarified butter	Butter	Each grouped separately.
	Ghee on the plate/ table	
Cheese and paneer	Cheese as: (grated cheddar/mozarella, spread and all types)	Retained
	Paneer curry(paneer butter masala/kadai paneer)	
	Paneer tikka	
Ice creams & Milkshakes	Icecreams*include cup & stick icecreams	Retained

Food groups	Food group components	Change in the new 68 food groups
	Milkshakes	
Low calories seasonal fruits	Orange	All seasonal fruits combined.
	Purple grapes	
	Watermelon	
	Litchi	
	Amla	
	Jamun	
	Custard apple	
High calories seasonal fruits	Raw mango	
	Ripe mango	
	Green peas (palya / sambhar / snacks / upma)	
	Plum	
	Jackfruit	
Seasonal green beans	Avrekalu	Retained
	Green peas	
Sweet corn	Boiled / roasted corn	Combined into cooked vegetables

APPENDIX S

Table 9.2: Correlation between the 68 food groups constructed using the 24-hour recall and the FFQ

Food groups	Spearman's rho (ρ)
BEVERAGES	
Tea and coffee	0.72**
Cow's milk	0.64**
Fermented dairy products	0.36**
Flavoured nutrient enriched sweetened supplements	0.52**
Flavoured sweetened beverages	NR ^a
Therapeutic beverages	0.30**
Soups	0.24**
Fresh fruit juices	0.33**
FRUITS	
Other Fruits	0.35**
Banana	0.35**
Apple	0.38**
Pomegranate	0.27**
Sweet lime	0.12*
NUTS, SEEDS AND DRIED FRUITS	
Dried fruits	0.35**
Dates and raisins	0.31**
Nuts and seeds	0.25**
Almonds	NR ^a
CEREAL, PULSE AND VEGETABLES INCLUDING MAIN DISHES AND SIDES	
Plain boiled white rice	0.42**
Spice seasoned/ flavoured rice	0.10**
Unpolished rice	0.34**
Rice with dal /sambhar	NR ^a
Idly	0.19**
Rice and greens preparations	0.03**
Curd rice	0.23**
Upma Poha etc.	0.20**
Dosa and masala dosa	0.17**
Fried cereal and pulses	0.22**
Fried pulse preparations	0.17**
Chapathi	0.43**
Processed shop bought western style breads and	0.41**
Rice roti & kadabu	0.16**
Ready to eat breakfast cereal	0.19**
Millet preparation	0.25**
Ragi ball	0.71**
Traditional whole and split pulse preparations	0.11**
Roots and tuber palyas	0.14**
Other vegetables sides	0.18**
Traditional style GLV sides	0.16**
Other GLV sides	0.17**

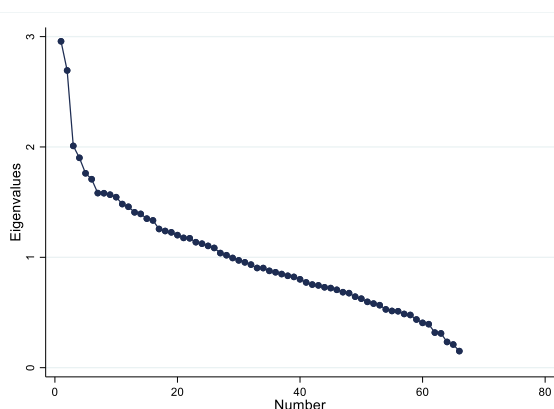
Food groups	Spearman's rho (ρ)
Raw vegetables	0.31**
Kosambari (traditional lentil vegetable salad)	0.16**
NON-VEGETARIAN INCLUDING MAIN AND SIDE DISHES	
Chicken fry and curry/ sambhar	0.26**
Chicken biriyani	0.08
Fish	0.24**
Red meat	0.26**
Boiled egg	0.16**
Egg preparations	0.16**
CONDIMENTS	
Pickles, papads, chutneys and chutney powders	0.27**
Western condiments	0.16**
ADDED SUGAR, SWEETS AND DESSERTS	
Added sugar	0.57**
Chocolate	0.16**
Creamless and cream cake	0.12**
Sweet, cream & salted biscuits	0.37**
Traditional cereal based sweet preparation	0.08
Traditional shop bought fried sweet preparation	0.06
Western style desserts	NR ^a
SAVOURY SNACKS AND FAST FOOD	
Medium calories fried savoury snacks	0.16**
High calories fried savoury snacks	0.09**
Puff pastry snacks	0.05**
Chats	NR ^a
Fast food (pizza and burger)	NR ^a
DAIRY PRODUCTS	
Curd/ yogurt	NR ^a
Ghee	NR ^a
Butter	NR ^a
Cheese and paneer	-
Milkshakes and ice creams	0.27**
SEASONAL FOODS	
Seasonal fruits	0.08
Seasonal green beans and green peas	0.03
Foods highlighted in orange show strong and moderate correlation and the rest in black font show some correlation.	
^a NR means Not Reported on 24-hour recall data and hence correlation co-efficient was not computed.	

APPENDIX T

PCA analysis of 24-hour data for the interpretation of validation approach 3 results

- a) Figure 9.2 shows the scree plot for the 66 food group PCA of 24-hour data, and based on break of scree-plot that starts to occur at the 6th point, indicated the first 5 components had to be retained.

Figure 9.2: Scree plot, PCA of 24-hour variables (n=510)



- b) Interpretation of PCA: Table 9.6 shows their factor loadings for the first five components/ patterns without rotation. 0.1 was chosen as a cut-off based on interpretability of patterns. Foods with factor loadings ≥ 0.1 were frequently consumed by women, whilst foods with factor loadings ≤ -0.1 were infrequently consumed by women. Foods with factor loadings close to 0 were non-discriminatory for that pattern.
- c) Component characteristics: All components were not clearly identifiable as healthy or unhealthy. Component 1 showed some characteristics of a Vegetarian-Urban diet pattern. Component 2 showed some characteristics of a traditional Vegetarian pattern. Components 3 & 4 showed characteristics of a Snack & takeaway preference pattern. Component 5 showed characteristics of a Non-vegetarian home cooking & takeaway preference pattern.
- d) Overall component 2 (compared to rest of the components) showed higher factor loadings for the most number of commonly consumed staple foods such as milk, fermented dairy (buttermilk, raitha), flavoured nutrient enriched beverage supplements, apple,

pomegranate, dates & raisins, other nuts & seeds, almonds, white rice, ragi ball, traditional pulse preparations, added sugar in beverages. This component showed negative factor loadings for less commonly eaten foods such as dosa, vada, puri. This is relatable to foods that a single 24-hour recall can pick up and, probably a reason for component 2 showing narrower limit of agreement & best correlation, compared to other components 1, 3, 4 & 5. The other components showed high factor loadings for staple foods, but showed high factor loadings for more number of less commonly consumed foods (which do not appear in component 2), such as ready to eat breakfast cereals, chocolates in pattern 1; soups, western style breads and pasta, biscuits in component 3; rice and greens and rice roti and kadabu in component 4 and unpolished rice, chicken biriyani and home-made sweets in component 5.

Table 9.5: Unrotated PCA table of 66 food groups from 24-hr data, showing factor loadings of the first 5 diet patterns (n=510)

Food groups	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
Tea & coffee	-0.15	-0.02	0.41	0.05	-0.10
Cows milk	0.14	0.41	-0.11	0.14	0.15
Fermented dairy products	0.04	0.14	-0.13	-0.02	0.08
Flavoured nutrient enriched sweetened supplements	0.12	0.35	-0.11	0.15	0.20
Flavoured sweetened beverages	0.05	-0.06	0.02	0.09	-0.07
Therapeutic beverages	0.10	-0.04	-0.17	0.07	-0.09
Soups	0.00	0.01	0.19	0.01	0.02
Fresh fruit juices	0.14	0.05	0.06	0.00	0.06
Other fruits	0.06	-0.02	-0.15	0.14	0.01
Banana (yelakki and robusta)	0.01	0.08	0.17	0.09	0.01
Apple	0.00	0.14	-0.09	0.12	-0.14
Pomegranate	0.01	0.14	-0.05	-0.03	-0.05
Sweetlime	0.01	-0.05	0.02	0.07	0.24
Dried fruits (figs, prunes & apricots)	0.26	-0.05	-0.06	0.11	-0.02
Dates and raisins	0.35	0.17	0.08	-0.21	-0.04
Other nuts and seeds	0.41	0.11	0.11	-0.27	-0.03
Almonds	0.38	0.09	0.06	-0.23	-0.01
Plain boiled white rice	-0.22	0.35	0.00	-0.03	-0.09
Spice seasoned rice preparations	0.11	0.01	0.01	-0.05	0.24
Unpolished rice	-0.03	-0.09	-0.02	0.03	0.25
Idly	0.00	-0.10	-0.24	-0.08	-0.18
Rice and greens preparations	0.03	0.00	-0.06	0.15	0.05
Curd rice	0.09	-0.09	-0.02	-0.11	0.07
Cereal preparations (Upma etc.)	0.07	-0.07	0.13	0.09	-0.01

Food groups	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
Dosa and masala dosa	0.06	-0.15	-0.13	-0.09	0.02
Fried cereal dishes (Poori etc.)	0.07	-0.11	0.14	0.11	-0.02
Fried pulse preparations (Vada etc.)	0.02	-0.11	-0.27	0.16	-0.14
Chapathi	0.17	-0.03	0.13	0.22	-0.27
Western style breads & pasta etc.	-0.05	-0.05	0.22	0.10	-0.06
Rice roti & kadabu	0.02	-0.07	-0.10	0.17	0.13
Ready to eat breakfast cereals	0.11	-0.04	-0.07	0.29	-0.06
Millet preparations	0.14	-0.09	-0.02	0.03	0.09
Ragi ball	-0.21	0.29	-0.14	-0.14	0.09
Traditional pulse preparations	-0.13	0.24	-0.17	0.00	-0.28
Root and tuber palyas	0.06	-0.05	-0.07	0.10	-0.06
Other vegetables sides	0.10	0.02	0.16	0.24	-0.22
Traditional style GLV sides	0.00	0.08	-0.04	0.01	0.11
Other GLV	0.07	0.04	0.00	0.03	-0.29
Raw vegetables	0.18	-0.02	-0.05	0.01	0.15
Kosambari (traditional salad)	0.03	0.04	0.01	-0.08	-0.02
Chicken fry and curry/ sambhar	-0.14	-0.09	0.09	-0.09	0.26
Chicken biriyani	-0.05	-0.07	0.07	-0.12	0.11
Fish preparations	-0.05	-0.04	0.06	-0.04	-0.09
Red meat preparations	-0.02	-0.08	0.04	-0.17	0.04
Boiled egg	-0.04	-0.02	-0.05	0.04	-0.02
Egg preparations	0.00	0.00	-0.02	0.22	0.13
Indian condiments (pickles etc.)	0.14	-0.17	-0.26	0.09	0.07
Western condiments (ketchup etc.)	0.01	0.02	-0.08	0.02	-0.02
Added sugar in beverages	0.00	0.31	0.27	0.17	0.08
Medium calories fried savoury snacks	0.13	0.01	-0.02	-0.11	-0.13
High calories savoury fried snacks	0.03	-0.02	-0.06	0.04	-0.04
Puff pastry snacks	0.02	-0.03	0.02	0.01	0.00
Chocolate	0.14	-0.04	0.12	-0.03	0.13
Cakes	0.07	-0.08	0.07	-0.17	-0.08
Biscuits	-0.01	0.04	0.21	0.13	0.02
Traditional, home-made sweets	0.07	0.00	0.02	0.10	0.10
Traditional shop bought sweets	0.08	0.05	-0.02	0.05	-0.13
Chats	0.07	-0.09	0.00	0.17	0.11
Fast food (pizza and burger)	0.02	-0.09	0.07	-0.05	-0.13
Curd/ yogurt	0.14	0.02	0.05	0.11	0.01
Ghee	-0.03	-0.02	0.14	0.13	0.01
Butter	0.07	0.07	0.04	0.16	0.01
Cheese & paneer	0.05	-0.09	0.05	0.06	-0.06
Milkshakes & Icecreams	0.05	-0.09	0.07	0.05	0.17
Seasonal fruits	0.06	0.00	-0.03	0.11	0.07
Seasonal green beans & green peas	0.06	-0.02	0.05	-0.16	-0.10

Lighter shading: positive factor loadings ≥ 0.1 ; Darker shadings: negative factor loadings ≤ -0.1

APPENDIX U: Ethical Approvals

Ethics approval letter from C.S.I Holdsworth Memorial hospital

FAX : 0091 - 821 - 2565607
E-mail : csihmh@bsnl.in
: csihmh@hotmail.com



☎: 4007000 & 4266370-3
Emergencies : 2420102
website : www.csihmh.com

C.S.I. Holdsworth Memorial Hospital

P.B. NO. 38, MANDI MOHALLA, MYSORE-570 001, INDIA.

Institutional Ethics Committee

11th April 2016

Ms. Anvesha Mahendra,
Nutritionist (PhD candidate),
Epidemiology Research Unit
CSI Holdsworth Memorial Hospital,
Mysore

&

Dr. GV Krishnaveni,
Senior Scientist (local supervisor)
Epidemiology Research Unit
CSI Holdsworth Memorial Hospital,
Mysore

Dear Dr. GV Krishnaveni & Ms Anvesha Mahendra,

The hospital's Ethics Committee reviewed and discussed your application for conducting the study titled "Diet, lifestyle patterns and nutritional biomarkers as risk factors for Gestational diabetes in urban India."

The following procedures were carried out -

The committee members reviewed and discussed your application dated 30th January 2016, and sent the feedback and comments to the Chairman. Members reviewed the revised project proposal and protocols which have been modified as per the instructions of the Institutional Ethics Committee.

Members reviewed the Information sheet and consent form in English and Kannada. The Chairman of the Ethics Committee reviewed the ethical considerations, and approved the study on behalf the Ethics Committee.

The following members of the Ethics committee reviewed the application and the responses to the comments, and sent their feed back to the Chairman of the Ethics Committee:

C.S.I. Holdsworth Memorial Hospital, Mysore

No	Name	Gender	Role in the Ethics Committee	Affiliation with Institution
1	Prof. PSS Sundar Rao	Male	Ex. Professor of Biostatistics/ Chairman of the committee	No
2	Dr. SC Karat	Male	Clinician (Pediatrician)/ Secretary of the committee	Yes
3	Dr. Richard Joseph	Male	Scientist/ Member	No
4	Dr. Syed Zakiuddin Ali	Male	Scientist/ Member	No
5	Dr. P H Upadya	Male	Clinician (Physician)/ Member	Yes
6	Mr. A C Narendra	Male	Legal counsel/ Member	No
7	Rev. Devakumar KP	Male	Social activist and spiritual leader/ Member	No
8	Ms. Maya Sitaram	Female	Lay person (Social activist)/ Member	No

With best wishes,



Dr. SC Karat
Secretary,
Institutional Ethics Committee

FAX : 0091 - 821 - 2565607
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: csihmh@hotmail.com



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C.S.I. Holdsworth Memorial Hospital

P.B. NO. 38, MANDI MOHALLA, MYSORE-570 001, INDIA.

Institutional Ethics Committee Decision

11th April 2016

Ms. Anvesha Mahendra,
Nutritionist (PhD candidate)
Epidemiology Research Unit,
CSI Holdsworth Memorial Hospital, Mysore

&

Dr. GV Krishnaveni,
Senior Scientist (Local supervisor)
Epidemiology Research Unit,
CSI Holdsworth Memorial Hospital, Mysore

Dear Dr. GV Krishnaveni & Ms Anvesha Mahendra,

On behalf of the Chairman, I am pleased to inform you that the members of the CSI Holdsworth Memorial Hospital Ethics Committee have approved your observational study titled **"Diet, lifestyle patterns and nutritional biomarkers as risk factors for Gestational diabetes in urban India"** to be conducted in the present form.

Remarks:

The Institutional Ethics Committee expects to be informed about the progress of the study, any adverse effects occurring in the course of the study, and any changes in the protocol and participant information sheet and informed consent. The committee also asks you to provide a copy of the final report.

Dr. Krishnaveni is a member of the Ethics Committee. However she was not involved in the voting and decision making process of this proposal. The Ethics Committee is organized and operated according to the requirements of Good Clinical Practice and according to the guidelines of the Indian Council of Medical Research (ICMR).

With best wishes,

Dr. SC Karat
Secretary, Institutional Ethics Committee

Ethics approval letter from Bangalore Baptist hospital

Bangalore Baptist Hospital

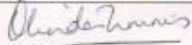
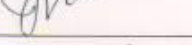
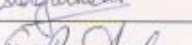
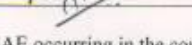
Institutional Review Board



Approval letter (Ethics Committee)

Name of PI	Ms. Anvesha Mahendra M & Dr.Nalini Arun Kumar
Study title	Diet, lifestyle patterns and nutritional biomarkers as risk factors for Gestational Diabetes in urban India
Date of approval	22/03/2015

The Institutional Review Board Bangalore Baptist Hospital has reviewed and approved your study.

IRB BBH	Designation	Signature
Dr. Ashish Chrispal	Chairperson	
Dr. Olinda Timms	Member (Ethicist)	
Dr. Anna Oommen	Member (Basic Scientist)	
Dr. Jay Warrior	Member (Lay person)	
Dr. George Korula	Member (Clinician)	
Mrs. Sangeeta Udgaonkar	Member (Legal expert)	
Dr.Jai Prakash.R	Member (Basic Scientist)	
Dr. Gift Norman	Member secretary	

The IRB BBH expects to be informed about the progress of the study, any SAE occurring in the course of the study, any changes in the protocol and patient information/informed consent and asks to be provided a copy of the final report.



Research Department, Community Health Block, Bangalore Baptist Hospital,
 Bellary Road, Hebbal, Bangalore - 560 024
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Ethics approval letter from Cloudnine hospital

**INSTITUTIONAL ETHICS COMMITTEE, CLOUDNINE HOSPITAL,
BANGALORE**

CERTIFICATE OF APPROVAL

This is to certify that the Project No. **IEC/C9791/2402/16002/V01**, entitled “**BANGLES (Bangalore Nutrition Gestational diabetes LiFEstyle Study)**” submitted by **Ms Anvesha Mahendra**, has been approved by our **Institutional Ethics Committee** on **16/04/2016** and this approval is valid for a period of three years or the duration of the project, whichever being less.

A handwritten signature in black ink, appearing to read 'Shridhar Rao', with a horizontal line drawn through it.

Mr Shridhar Rao,

Chairman, Institutional Ethics Committee,

Cloudnine Hospital,

Bangalore.

Ethics approval letter from Southampton General hospital

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Home Submissions

My Submissions (1)

Category	Submission ID	Project Title	Status
A	20377	BANGLES (Bangalore Nutrition Gestational diabetes Lifestyle Study)	Approved

View
→ Create Amendment
Request Extension

Freedom of information | Terms & Conditions | University Contacts | IT Help
Activate Windows
Report a problem with this system to ISolutions ServiceLine

21:04
16/11/2020

Status: Approved

Category: Category A

Submitter's Faculty: Faculty of Medicine (FMED)

Original Submission 20377 (Created 28/04/2016)

17/07/2016 08:12:49 - Committee: Approved

Dear Anvesha, RE: 20377 - BANGLES (Bangalore Nutrition Gestational diabetes Lifestyle Study)

Thank you for submitting your amendments relating to the above study. I am pleased to inform you that full approval has now been granted by the Faculty of Medicine Ethics Committee. Please consider the following suggestion regarding the issue of linked anonymity. Participants all have an allocated study number. We appreciate that in a busy research environment you may wish to use the participant's name on the questionnaire on the day of data collection. However, we suggest that, once data has been collected, questions 1-5 from form 2 (identifying data) are stored separately from the body of the questionnaire which can then be identified by study number only. Approval will be valid once the University Research Governance office have provided confirmation of insurance cover and will end on the date specified in your IRGA form. Please note the following points: â€¢ the above ethics approval number must be quoted in all correspondence relating to your research, including emails; â€¢ if you wish to make any substantive changes to your project you must inform the Faculty of Medicine Ethics Committee as soon as possible. Please note that this letter will now constitute evidence of ethical approval. We wish you success with your research.

Yours sincerely,

Dr Catherine Hill Faculty of Medicine Ethics Committee

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