Dietary management of gestational diabetes in New Zealand

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Abstract

Background: The prevalence of gestational diabetes mellitus (GDM), a condition of glucose intolerance in pregnancy with significant health implications for mother and infant, is rising. Diet is central to managing GDM but little is known about the diets of women with GDM and how GDM is managed through diet in New Zealand.
Objectives: To describe the diets and investigate the dietary management of women with GDM in New Zealand through four perspectives: an estimation of the prevalence of GDM in New Zealand; adherence to dietary guidelines and description of dietary patterns of women with and without GDM and determination of whether these are associated with the development of GDM; evaluation of dietetic services provided for women with GDM, and exploration of women's perceptions of dietary advice and experiences in managing GDM through diet.
Methods: The prevalence of GDM in pregnant women participating in the Growing Up in New Zealand (GUiNZ) longitudinal birth cohort was determined using clinical coding data, laboratory results and self-reported data. Adherence to dietary guidelines and dietary patterns were compared between women with and without GDM participating in GUiNZ from food frequency questionnaires. Dietetic practice in the management of GDM in New Zealand and the level of dietetic services provided were evaluated through a cross-sectional survey. Semi-structured interviews with women with GDM were analysed thematically to explore women's perceptions of dietary recommendations and the influence of these on dietary decisions during pregnancy and beyond.
Findings: Prevalence of GDM among 6,822 women participating in GUiNZ combining all data sources was 6.2% but varied significantly according to data source (3.8% using self-reported data to 6.9% from laboratory data). Dietary data were available from 5,384 women in GUiNZ. Adherence to food group recommendations was poor in both women with and without GDM and was not associated with odds of developing GDM. However, mean dietary pattern scores for "Junk" and "Traditional/White bread" dietary patterns were significantly lower in women with GDM compared to women without GDM and were negatively associated with having GDM. Thirty-three dietitians participated in the survey of dietetic practice and reported significant variation in the services provided and management recommendations. Over a quarter of dietitians felt the services provided were inadequate but few evaluated their services. Three interconnected themes described the experience and perceptions of eighteen women with GDM in managing their diet through GDM: managing GDM is a balancing act; using the numbers as evidence, and the GDM timeframe. Women perceived the purpose of dietary advice to be control of blood glucose results. Women's relationships with healthcare providers had a significant influence on their perception of advice and dietary intentions.
Conclusions: A consistent national approach to diagnosis and reporting GDM prevalence is needed to monitor changing prevalence and to facilitate resource allocation and service planning. New Zealand-specific evidence-based guidelines for the dietary management of GDM are needed to improve consistency in services and provide a benchmark for the ongoing evaluation of dietetic management of GDM. Healthcare professionals have a significant influence on women's dietary behaviours. A woman-centred approach is necessary to achieve optimal outcomes for mother and infant.

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List of abbreviations

ADHB	Auckland District Health Board
ADI	Acceptable daily intake
aHEI	Alternate Healthy Eating Index
aMED	Alternate Mediterranean Diet
aOR	Adjusted odds ratio
ARFS	Australian Recommended Food Score
BGLs	Blood glucose levels
BMI	Body mass index
CHO	Carbohydrate
CI	Confidence interval
CMDHB	Counties Manukau District Health Board
COREQ	Consolidated Criteria for Reporting Qualitative Studies
DASH	Dietary Approaches to Stop Hypertension
FDA	Food and Drug Administration
FNGPB	Food and Nutrition Guidelines for Pregnant and Breastfeeding Women
GCT	Glucose challenge test
GDM	Gestational diabetes mellitus
GEMS	Gestational Diabetes Mellitus Trial of Diagnostic Detection Thresholds
GI	Glycaemic index
GUiNZ	Growing Up in New Zealand
GWG	Gestational weight gain
HAPO	Hyperglycaemia and Adverse Pregnancy Outcomes
IADPSG	International Association of Diabetes and Pregnancy Study Groups
ICD	International Classification of Diseases
IOM	Institute of Medicine
IPAQ	International Physical Activity Questionnaire
IQR	Interquartile range
KW	Kim Ward
MELAA	Middle Eastern/Latin American/African
MNT	Medical nutrition therapy
MOH	Ministry of Health
n	Number
NCEA	National Certificate of Educational Achievement
NHI	National Health Identifier

NZ	New Zealand
NZDep06	The New Zealand Deprivation Index 2006
NZDep2013	The New Zealand Deprivation Index 2013
OGTT	Oral glucose tolerance test
OR	Odds ratio
PDQS	Prime Diet Quality Score
PRAMS	Pregnancy Risk Assessment Monitoring System
RL	Robyn Lawrence
SD	Standard deviation
STROBE	Strengthening the reporting of observational studies in epidemiology
T2DM	Type 2 diabetes
WDHB	Waikato District Health Board

Chapter 1

Introduction

Background and context

The importance of the maternal diet during, and even before, pregnancy is well established (Godfrey & Barker, 2000; Harding, 2001). An adequate supply of nutrients for the growth and development of the fetus is a complex process partly dependent on maternal nutritional status which in turn depends on maternal dietary intake, nutrient stores, and obligatory requirements (Cetin, Alvino, Radaelli, & Pardi, 2007). Nutrient supply below or in excess of maternal and fetal requirements can have a negative impact on fetal growth and development (Desforges & Sibley, 2010). There is increasing evidence of the long-term effects of maternal obesity and exposure to over-nutrition *in utero* on the offspring in later life, such as higher rates of obesity (Eriksson, Sandboge, Salonen, Kajantie, & Osmond, 2015), cardiovascular disease (Eriksson, Sandboge, Salonen, Kajantie, & Osmond, 2014; Reynolds et al., 2013) and diabetes (Eriksson et al., 2014). Globally, the prevalence of overweight and obesity among women of childbearing age is rising (Amugsi, Dimbuene, Mberu, Muthuri, & Ezeh, 2017; Heslehurst et al., 2007; Kim, Dietz, England, Morrow, & Callaghan, 2007; Ratnasiri et al., 2019; Ward et al., 2020; Yaya & Ghose, 2019). Recent reports suggest up to half of women entering pregnancy are overweight or obese (Ratnasiri et al., 2019; Reynolds et al., 2020; Ward et al., 2020), putting themselves and their infants at risk of perinatal complications (Ovesen, Rasmussen, & Kesmodel, 2011) and long-term ill health (Battista, Hivert, Duval, & Baillargeon, 2011). One of the most common complications of pregnancy, with prevalence rising concomitantly with the rising prevalence of overweight and obesity (Ferrara, 2007; Hunt & Schuller, 2007; Kim et al., 2016) is gestational diabetes mellitus (GDM).

GDM definition and pathophysiology

GDM is a form of carbohydrate intolerance first diagnosed in pregnancy, characterised by blood glucose concentrations above normal but below the threshold of overt diabetes (American Diabetes Association, 2019a; International Association of Diabetes and Pregnancy Study Groups Consensus Panel et al., 2010; World Health Organization, 2013). The normal physiological adaptations to pregnancy includes progressive insulin resistance that begins in mid-pregnancy and increases throughout the third trimester (P M Catalano et al., 1993). Insulin resistance appears to result from a combination of increased maternal adiposity and insulin-desensitizing effects of hormones produced by the placenta (Barbour et al., 2007; Newbern & Freemark, 2011). These adaptations are thought to occur to ensure adequate supply of glucose to the developing fetus (Newbern & Freemark, 2011). In healthy pregnancies, circulating maternal glucose is regulated to stay within normal limits in the face of insulin resistance through pancreatic beta-cell expansion leading to increased insulin secretion in the third trimester (Butler et al., 2010). However, in women with GDM there is a greater degree of

insulin resistance which leads to maternal hyperglycaemia and excess transport of glucose across the placenta to the developing fetus (di Cianni, Miccoli, Volpe, Lencioni, & del Prato, 2003). While the precise aetiology of GDM remains uncertain, GDM is thought to result from an inability to increase insulin production (Catalano et al., 1993), a degree of pre-existing insulin resistance, a reduced ability to suppress endogenous glucose production (Barbour et al., 2007; Catalano, Huston, Amini, & Kalhan, 1999), genetic predisposition (Zhang et al., 2013), or a combination of these factors (Buchanan & Xiang, 2005). The aetiology and risk factors associated with GDM share many similarities with those for type 2 diabetes (Ben-Haroush et al., 2004; Solomon et al., 1997), and women who develop GDM have an almost ten-fold increased risk of developing type 2 diabetes after pregnancy (Vounzoulaki et al., 2020). Pregnancy is thus thought to act as a transient window to the future health of women (Catov & Margerison-Zilko, 2016; Poon, Yeung, Boghossian, Albert, & Zhang, 2013) and the diagnosis of GDM can act as a harbinger for type 2 diabetes, potentially leading to interventions to either prevent or slow the progression to life-long type 2 diabetes (Cheung & Byth, 2003; Ratner et al., 2008).

Consequences of GDM

GDM has been associated with a number of negative health consequences for both mothers and their infants. During the perinatal period, women with GDM are at increased risk of gestational hypertension and pre-eclampsia (Schneider, Freerksen, Röhrig, Hoeft, & Maul, 2012; Vambergue et al., 2002), premature rupture of membranes and caesarean section (Xiong, Saunders, Wang, & Demianczuk, 2001). Infants born to women with GDM are at increased risk of neonatal hypoglycaemia (Jensen, Sørensen, Feilberg-Jørgensen, Westergaard, & Beck-Nielsen, 2000; The HAPO Study Cooperative Research Group, 2008), needing care in the neonatal unit (Jensen et al., 2000), being large-for-gestational-age and macrosomia (Jensen et al., 2000; Xiong et al., 2001). Large infant size at birth can cause further complications during delivery including shoulder dystocia, birth trauma or need for early or operative delivery (Boulet, Salihu, & Alexander, 2004). The risk of poor perinatal outcomes has a linear relationship with maternal glucose concentrations (The HAPO Study Cooperative Research Group, 2008) even when levels of glucose intolerance are below the threshold for GDM (Sermer et al., 1995; The HAPO Study Cooperative Research Group, 2008) and worse outcomes have been reported with poorer control (Bartha, Martinez-Del-Fresno, & Comino-Delgado, 2000; Feng et al., 2018; Hedderson, Ferrara, & Sacks, 2003; Landon et al., 2009; Langer et al., 1994; Langer, Yogev, Most, & Xenakis, 2005; Shah & Sharifi, 2020; Sweeting et al., 2016; Yefet, Schwartz, Sliman, Ishay, & Nachum, 2019). For example, in a study of 996 women with GDM birthing at a provincial hospital in China, women with a higher fasting plasma glucose concentration at their last antenatal visit prior to delivery

had greater odds of stillbirth, hydramnios, premature delivery, and an infant requiring admission to the neonatal care unit and having respiratory distress syndrome (Feng et al., 2018).

The effects of GDM are not just limited to the perinatal period. Women with GDM are at increased risk of developing GDM again in a subsequent pregnancy (Getahun, Fassett, & Jacobsen, 2010), face a 3-fold greater risk of developing metabolic syndrome (Lauenborg et al., 2005) and an increased risk of developing type 2 diabetes (Vounzoulaki et al., 2020). Furthermore, infants born to women with GDM may have poorer neurodevelopment (Nomura et al., 2012; Ornoy, Wolf, Ratzon, Greenbaum, & Dulitzky, 1999) and are at increased risk of obesity, impaired glucose tolerance, the metabolic syndrome, cardiovascular disease and diabetes in later life (Clausen et al., 2008; Kearney et al., 2018; Lowe, Lowe, et al., 2019; Lowe, Scholtens, et al., 2019; Nehring, Chmitorz, Reulen, von Kries, & Ensenauer, 2013; Pathirana, Roberts, & Andraweera, 2020; Pettitt & Knowler, 1998; Tam et al., 2008; Yu et al., 2019; Zhu et al., 2016). Female infants born to women with GDM are also at increased risk of developing GDM or diabetes during pregnancy themselves, thereby perpetuating an intergenerational cycle of obesity and diabetes (Catalano, 2003; Dabelea & Crume, 2011). Clearly, strategies to prevent or better manage GDM would be beneficial in reducing risks to mother and infant and put a halt to this cycle.

Risk factors for the development of GDM

Numerous risk factors for the development of GDM have been identified. Advanced maternal age, family history of diabetes, higher pre-pregnancy body mass index (BMI) and ethnicity are well established risk factors (di Cianni et al., 2003; Hedderson et al., 2012; Solomon et al., 1997). Increased maternal pre-pregnancy BMI is perhaps the greatest modifiable risk factor for GDM. Risk of GDM is estimated to be between two to nine times higher in overweight and obese women compared to women with a BMI in the healthy range (Chu et al., 2007). A systematic review involving over 6,000 women found the risk of GDM increased by 0.92% for every unit increase in a woman's BMI across all BMI categories (Torloni et al., 2009). It is thought that women who enter pregnancy obese already have some degree of insulin resistance due to increased fat mass (Grundy, 2004) and therefore are at increased risk of GDM due to the additive effect on the progressive insulin resistance associated with advancing gestation (Catalano et al., 1999). High rates of gestational weight gain, or weight gain above the Institute of Medicine (IOM) recommendations, particularly in early pregnancy, have been associated with an increased risk of GDM (Carreno et al., 2012; Hedderson, Gunderson, & Ferrara, 2010; Tomedi, Simhan, Chang, McTigue, & Bodnar, 2014). This may be because weight gained early in pregnancy is disproportionally fat mass (van Raaij, Peek, Vermaat-Miedema, Schonk, & Hautvast,

1988; van Raaij, Schonk, Vermaat-Miedema, Peek, & Hautvast, 1989) which may lead to greater insulin resistance (Kohrt et al., 1993). In 2009, the IOM released updated guidelines for appropriate weight gain during pregnancy (Institute of Medicine & National Research Council, 2009). Whilst previous IOM guidelines considered only the risk of low birthweight and preterm birth, the 2009 guidelines also consider the risk of infants born small- or large-for-gestational age, the mother's risk for an unplanned caesarean section and postpartum weight retention (Rasmussen, Catalano, & Yaktine, 2009). Despite wide adoption of these guidelines, few women achieve gestational weight gains within recommendations (Goldstein et al., 2018; Rogozińska et al., 2019). In analyses of over 4,000 women from 16 countries, Rogozińska et al. (2019) found only a third of women gained weight within the IOM recommendations, with 37% of women gaining above and 29% gaining below recommendations (Rogozińska et al., 2019). Similar findings were reported in a meta-analysis of data from over one million women by Goldstein et al. (2018). Both studies found greater proportions of overweight and obese women gained weight in excess of recommendations compared to healthy weight women (Goldstein et al., 2018; Rogozińska et al., 2019), thus adding to their already elevated risk of developing GDM.

Rates of GDM vary significantly among women of different ethnic groups. Women of Asian, Indian, Hispanic and Pacific descent appear to have a higher risk of developing GDM (Berkowitz, Lapinski, Wein, & Lee, 1992; Hedderson, Darbinian, & Ferrara, 2010; Savitz, Janevic, Engel, Kaufman, & Herring, 2008). It has been proposed that different ethnicities have different tolerance to adiposity and the risk of GDM attributed to weight gain varies across different ethnicities. In a study measuring weight, skinfold thickness and bioelectrical impedance in 728 women, an increase in weight, skinfold thickness and total fat mass were all positively associated with the development of GDM (Sommer et al., 2014). The authors also found that compared to women of European ethnicity, women of South Asian descent had an almost three times greater odds of developing GDM with equivalent increases in truncal fat and pre-pregnancy BMI (Sommer et al., 2014). Prevalence of GDM is even higher in certain ethnicities when living in countries different to their native birthplace. In a study utilising the Kaiser Permanente of Northern California Gestational Diabetes Register and birth records from 216,089 pregnancies, Hedderson et al. (2010) found being born outside the country of residence was associated with a significantly increased risk of GDM for black, Asian Indian, Filipina, Pacific, Chinese, Mexican and non-Hispanic white women (Hedderson, Darbinian, et al., 2010). This is perhaps due to the effect of acculturation and increased availability of calorie-dense foods and sedentary lifestyles in Western cultures as has been demonstrated in numerous studies exploring acculturation and its

influence on chronic disease risk (Gilbert & Khokhar, 2008; Huang et al., 1996; Park et al., 2005; Sundquist & Winkleby, 2000; Ziegler et al., 1993).

Diet as a risk factor for GDM

The influence of diet on the development of GDM has been a strong focus in the literature and a number of foods and nutrients have been associated with risk of developing GDM. While there have been numerous studies in this area, findings have been inconsistent (Aminianfar et al., 2020; Bertolotto et al., 2010; Bo et al., 2001; Bowers, Tobias, Yeung, Hu, & Zhang, 2012; Gonzalez-Clemente et al., 2007; Qiao et al., 2021; Radesky et al., 2008; Saldana, Siega-Riz, & Adair, 2004; Wang et al., 2000). Part of the reason for these mixed results may be the heterogeneity of studies. Research conducted in this area varies considerably in terms of sample size, timing and time-period captured by dietary assessment (pre-pregnancy, early pregnancy or mid-pregnancy), method of dietary assessment (single or multiple 24-hour recalls or food frequency questionnaires) and in categorization of cases and controls, with some combining women with impaired glucose tolerance and GDM and with use of different diagnostic criteria for the diagnosis of GDM. Lack of clear associations between dietary components and risk of GDM may also be due to the focus on single foods or nutrients. This narrow focus fails to take into account the synergistic or inhibitory effects foods can have on digestion and metabolism when consumed together (Hu, 2002). Dietary pattern analysis evaluates outcomes based on a pattern of foods consumed in combination and better reflects eating behaviours in the 'real world'. This approach is thought to be useful when a number of dietary factors have been associated with a condition, as it goes beyond individual foods and nutrients and examines the combined effect of the whole diet (Hu, 2002). Whilst there are some differences seen in studies examining dietary patterns and their association with the development of GDM in terms of their methodology and findings, there are some consistencies in the dietary patterns which have been associated with risk of developing GDM. For example, Tobias et al. (2012) used the dietary index approach to assess adherence of 15,254 women in the Nurses' Health Study II to three previously identified healthful dietary patterns: the alternate Mediterranean diet (aMED); the Dietary Approaches to Stop Hypertension (DASH) diet, and the alternate Health Eating Index (aHEI), and their risk of developing GDM. Greater adherence to any of the dietary patterns studied was associated with a reduced risk of GDM (Tobias et al., 2012). Similarly, in a study of 1,076 women from 10 Mediterranean countries, Karamanos et al. (2014) found higher scores on a Mediterranean Diet Index were associated with a reduced risk of GDM (Karamanos et al., 2014). These diets are typically characterised by a high intake of fruit, vegetables, whole grains, nuts and legumes, and a low consumption of red and processed meats (Appel et al., 1997; Fung et al., 2005; Kennedy, Ohls, Carlson,

& Flemin, 1995). Using factor analysis, Zhang et al. (2006) identified two major dietary patterns in the Nurses' Health Study II. The 'Prudent' dietary pattern was characterised by high intake of fruit, green leafy vegetables, poultry and fish, whereas the 'Western' pattern was characterised by a high intake of red meat, processed meat, refined grain products, sweets, French fries and pizza. Women in the highest quintile of the 'Western' pattern score and the lowest quintile of the 'Prudent' pattern score had a greater risk of GDM (Cuilin Zhang, Schulze, et al., 2006). Similarly, others have found dietary patterns high in red and processed meats, confectionary and fast food to be associated with an increased risk of GDM (Donazar-Ezcurra et al., 2017; Hassani Zadeh, Boffetta, & Hosseinzadeh, 2020; Schoenaker, Soedamah-Muthu, Callaway, & Mishra, 2015; Schoenaker, Mishra, Callaway, & Soedamah-Muthu, 2016; Shin, Lee, & Song, 2015) and diets rich in vegetables, fruit, legumes, fish and wholegrains or 'Mediterranean', 'Prudent' or 'Vegetable' dietary patterns, have been associated with a reduced risk of GDM (Assaf-Balut et al., 2018; Gicevic et al., 2018; Hassani Zadeh et al., 2020; Izadi et al., 2016; Schoenaker et al., 2015; Schoenaker et al., 2016; Tryggvadottir, Medek, Birgisdottir, Geirsson, & Gunnarsdottir, 2016; Zareei, Homayounfar, Naghizadeh, Ehrampoush, & Rahimi, 2018). The foods making up the dietary patterns associated with an increased or decreased risk of GDM in these dietary pattern studies show agreement with many of the findings in the single food or nutrient studies mentioned above and many can be explained through biologically plausible mechanisms. Foods typically considered in a 'Western' dietary pattern generally have high levels of saturated fats, nitrites and nitrosamines. High intakes of saturated fat can increase serum cholesterol, which has been associated with reduced insulin secretion (Hao, Head, Gunawardana, Hasty, & Piston, 2007) and intake of nitrites and nitrosamines has been associated with pancreatic beta-cell toxicity and reduced beta-cell function (Helgason, Ewen, Ross, & Stowers, 1982; Oh, Bae, Baek, Park, & Jun, 2018; Wilson, Mossman, & Craighead, 1983). The high consumption of red meat in 'Western' dietary patterns may also lead to high intakes of haem iron, a pro-oxidant increasing oxidative stress leading to further pancreatic beta-cell damage (Liu et al., 2008). Conversely, the reduced risk of GDM associated with 'Prudent', 'Mediterranean' or 'Vegetable' dietary patterns may be attributable to the high consumption of fibre, flavonoid and antioxidant rich fruit and vegetables in these diets. These may reduce GDM risk through their favourable effects on insulin sensitivity, glucose metabolism, and in reducing oxidative stress (Zatollah Asemi, Samimi, Tabassi, Sabihi, & Esmaillzadeh, 2013; Liese et al., 2005).

Whilst there is consistency in the relationship between particular dietary patterns and risk of GDM (Schoenaker et al., 2016), much of the research to date has been conducted in largely Caucasian populations (Bao, Tobias, et al., 2014; Tobias et al., 2012; Tryggvadottir et al., 2016; Zhang, Schulze,

et al., 2006), with many using data from the same cohort of women from the Nurses' Health Study II. Dietary data from the Nurses' Health Study II were collected during 1991 to 2001 using a food frequency questionnaire administered every four years (Solomon et al., 1997; Willett et al., 1988). Eating patterns are likely to change over time with the increasing diversity of food locally available (Kearney, 2010) and contemporary eating patterns are likely to be different to those seen in the Nurses' Health Study II. Furthermore, women may make changes to their diet when planning pregnancy or on becoming pregnant and therefore eating patterns around the time of conception and during pregnancy may be different to habitual dietary patterns (Hillier & Olander, 2017; Khan, Boyle, Lang, & Harrison, 2019). Studies evaluating dietary patterns in Asian populations have reported dietary patterns and their associations with GDM that are different to those seen in studies of largely Caucasian women (de Seymour et al., 2016; He et al., 2015). For example, in a cohort of predominantly Chinese women living in Singapore, de Seymour et al. (2016) found a 'Seafood-noodle' dietary pattern high in soup, fish, seafood and noodles but low in bread, legumes and pulses to be associated with a reduced risk of developing GDM. In another cohort of Chinese women living in China, He et al. (2015) found a 'Vegetable' dietary pattern, high in vegetables, beans, legumes, seaweed and nuts, to be associated with a reduced risk of developing GDM, whilst a 'Prudent' dietary pattern with some similarities to the 'Seafood-noodle' dietary pattern in de Seymour et al.'s study was not associated with GDM (He et al., 2015). However, differences in dietary assessment methods (24-hour recall in de Seymour et al. (2016) and food frequency questionnaire assessing intake over one week in He et al. (2015)) and GDM diagnostic criteria may have contributed to these different findings. There is clearly a need for further good quality research of adequate sample size and carefully planned dietary assessment to explore the associations between dietary patterns and GDM risk among populations of different ethnicities.

In New Zealand, the incidence of GDM is two to three times higher in women of Indian, Asian, Middle Eastern, Latin American or African, Pacific and Māori ethnic groups compared to women of European descent (Ministry of Health, 2014; National Women's Health, 2021; Yapa & Simmons, 2000). This may be due to genetic factors as well as a higher frequency of risk factors present in these population groups. The most recent New Zealand Health Survey found 63.4% of Pacific and 47.9% of Māori adults to be obese, compared to 29.3% in European and 15.9% in Asian ethnic groups (Ministry of Health, 2020a). Māori women are more insulin resistant compared to Europeans, independent of central adiposity and BMI status (McAuley, Williams, Mann, Goulding, & Murphy, 2002). Indian and Asian ethnic groups also have a tendency to greater central obesity, putting them at greater risk of diabetes (McKeigue, Shah, & Marmot, 1991). Studies exploring dietary intakes of pregnant women in New

Zealand have found the majority of women have suboptimal diets during pregnancy (Morton et al., 2014; Wall et al., 2016; Watson & McDonald, 2009). Using data involving 5,664 women in the Growing Up in Zealand study (GUiNZ), a pre-birth longitudinal cohort study investigating determinants of health and development in children born in New Zealand, Morton et al. (2014) found only 3% of women met dietary recommendations for pregnant women (Morton et al., 2014). In the same cohort of women, Wall et al. (2016) used factor analysis to extract four dietary patterns from food frequency questionnaire data. Compared to European women, Pacific and Māori women had higher scores on 'Junk' and 'Traditional/White bread' dietary patterns which were characterised by high intakes of confectionary, takeaways, processed meats, soft drinks, and fried foods and full-fat milk, white bread, spreads and low fibre/high sugar cereals respectively (Wall et al., 2016). A higher score on the 'Junk' dietary pattern was associated with lower adherence to dietary recommendations for pregnant women whereas a higher score on the 'Health conscious' dietary pattern, characterised by high loadings of vegetables, fruit, cheese and wholegrains, was associated with greater adherence to the dietary recommendations (Wall et al., 2016). A higher score on the 'Fusion/Protein' dietary pattern, characterised by high loadings for noodles, rice, pasta, green leafy vegetables, seafood, chicken, eggs and red meat, was associated with being born outside New Zealand and non-European ethnicity, particularly Asian ethnicity. Whether these differences in diet influence New Zealand women's risk of developing GDM has not been explored.

Diagnosis of GDM

The first criteria for GDM diagnosis were based on the identification of women with a high future risk of developing type 2 diabetes (O'Sullivan & Mahan, 1964). Over the years, additional risks to both mother and infant have been identified and a variety of diagnostic approaches have been developed taking these additional risks into account. Despite many calls for international consensus on GDM diagnostic criteria, there are still widespread differences in screening and diagnostic practices across the globe (Agarwal et al., 2015; Buckley et al., 2012). The landmark Hyperglycaemia and Adverse Pregnancy Outcomes (HAPO) trial was designed to clarify the risks of adverse outcomes associated with maternal glucose intolerance below the threshold of overt diabetes (The HAPO Study Cooperative Research Group, 2008). It was anticipated that this would provide data that could be used to derive international criteria for diagnosis and classification of GDM (International Association of Diabetes and Pregnancy Study Groups Consensus Panel, 2010). The results of the HAPO study showed a continuous graded association between higher maternal blood glucose and risk of adverse perinatal outcomes (The HAPO Study Cooperative Research Group, 2008). The International Association of Diabetes and Pregnancy Study Groups (IADPSG) used data from the HAPO study in

addition to the findings of other studies examining associations of maternal glycaemia with perinatal and long-term outcomes in offspring (Crowther et al., 2005; Jensen et al., 2008; Landon et al., 2009; Pettitt & Knowler, 1998) to come up with a consensus statement to serve as the basis for internationally endorsed criteria for the diagnosis and classification of diabetes in pregnancy (International Association of Diabetes and Pregnancy Study Groups Consensus Panel, 2010). As the HAPO study showed no clear threshold at which risks increase (The HAPO Study Cooperative Research Group, 2008), the IADPSG set diagnostic values based on the odds ratio of 1.75-fold the mean for selected outcomes of the HAPO study (the average glucose values at which odds for birth weight >90th percentile, cord C-peptide >90th percentile, and percent body fat >90th percentile reached 1.75 times the estimated odds of these outcomes at mean glucose values) (International Association of Diabetes and Pregnancy Study Groups Consensus Panel et al., 2010). The IADPSG guidelines suggest early screening for diabetes at the first prenatal visit using HbA1c, fasting or random blood glucose. A diagnosis of overt diabetes is made if HbA1c or fasting blood glucose values are equal or greater than 48 mmol/mol or 7.0 mmol/L. If random blood glucose is equal or greater to 11.1 mmol / L, a tentative diagnosis of overt diabetes should be confirmed using fasting blood glucose or HbA1c. If overt diabetes or GDM is not diagnosed through early screening, a two-hour 75 g oral glucose tolerance test (OGTT) is recommended at 24 – 28 weeks' gestation. A diagnosis of GDM is then made if any of the measured blood glucose values exceed the thresholds listed in Table 1 (International Association of Diabetes and Pregnancy Study Groups Consensus Panel et al., 2010). Although these diagnostic criteria were adopted by the World Health Organization (WHO) in 2013 (World Health Organization, 2013), there has been limited uptake by others and many countries continue to use alternative criteria leading to significant differences in prevalence estimates. This makes comparisons of research outcomes across studies internationally difficult (Agarwal, 2010; Jiwani et al., 2012).

In New Zealand, national guidelines for the screening, diagnosis and management of GDM were released by the Ministry of Health (MOH) in 2014 (Ministry of Health, 2014). While these guidelines advocate for early screening for diabetes in pregnancy as recommended by IADPSG, thresholds for diagnosis of GDM and overt diabetes in pregnancy are higher than that recommended by the IADPSG consensus guidelines (International Association of Diabetes and Pregnancy Study Groups Consensus Panel, 2010; Ministry of Health, 2014) (see Table 1) and are based on the New Zealand Society for the Study of Diabetes criteria which have been in place since 1992 (New Zealand Society for the Study of Diabetes, 1995; Simmons et al., 2006). Results of the Gestational Diabetes Mellitus Trial of Diagnostic Detection Thresholds (GEMS) study, which aims to compare perinatal outcomes in women diagnosed

with GDM using current criteria or those recommended by IADPSG, are anticipated to be available later this year (Crowther, 2015).

Table 1. Criteria for the diagnosis of GDM as recommended by IADPSG and MOH

Guideline	Screening method	Threshold for GDM diagnosis at 75 g-OGTT		
		Fasting	1 hr	2 hr
IADPSG	One-step[1]	≥5.1 mmol/L	≥10.0 mmol/L	≥8.5 mmol/L
MOH	Two-step[2]	≥5.5 mmol/L	-	≥ 9.0 mmol/L

GCT Glucose challenge test, *GDM* gestational diabetes mellitus; *IADPSG* International Association of Diabetes and Pregnancy Study Group, *MOH* Ministry of Health, *OGTT* Oral Glucose Tolerance Test. [1]Screening for overt diabetes is recommended using fasting plasma glucose, HbA1c or random plasma glucose at the first prenatal visit. [2]HbA1c measurement is recommended at <20 weeks' gestation: if ≥50 mmol/mol it is suggested women have probable undiagnosed diabetes, if 41 – 49 mmol/mol women should have an OGTT at 24 – 28 weeks with no need for a GCT, if ≤40 mmol/mol women are referred for a GCT and if 1 hr post glucose load ≥7.8 mmol/L referred further for an OGTT.

Much of the debate of what constitutes appropriate diagnostic criteria for GDM stems from the fact that there is a spectrum of glucose intolerance in pregnancy that is associated with adverse perinatal and long-term outcomes with no clear threshold at which risks increase (Hillier et al., 2007; Jensen et al., 2008; Sermer et al., 1995; The HAPO Study Cooperative Research Group, 2008). As the criteria suggested by IADPSG have lower blood glucose levels than most others currently in use, adoption of the IADPSG or WHO criteria will result in an increase in the number of cases of GDM diagnosed (Saeedi, Cao, Fadl, Gustafson, & Simmons, 2021). Some argue that this will overburden the health system, increase health costs, result in increased anxiety in women with a diagnosis of GDM (Agarwal et al., 2012; Cundy et al., 2014; He et al., 2019; Meloncelli et al., 2020) or that there is insufficient evidence to suggest justifiable benefit (Bilous, Jacklin, Maresh, & Sacks, 2021; Hillier et al., 2021). Others argue that the additional cost associated with higher rates of diagnosis and management of GDM has favourable 'return on investment' when considering the extra life-years gained and lower morbidity in women and their offspring as more women are identified and offered appropriate management interventions (Brown & Wyckoff, 2017; Mission, Ohno, Cheng, & Caughey, 2012; Werner et al., 2012).

Prevalence of GDM

Accurate estimation of GDM prevalence is important for service planning, funding allocation and research. Inaccurate estimation of GDM prevalence could result in inadequate or inequitable care. Calculating disease prevalence requires accurate determination of the presence of a diagnosis, appropriate counting of cases, and estimation of the total population under consideration (Bagley & Altman, 2016). Current estimates suggest GDM affects between 2 – 41% of pregnancies worldwide,

depending on the population studied and diagnostic criteria used (Behboudi-Gandevani, Amiri, Bidhendi Yarandi, & Ramezani Tehrani, 2019; Saeedi et al., 2021). Whilst GDM prevalence will vary depending on the population's background risk due to differences in ethnic make-up (Brown, Kapurubandara, & McGee, 2020; Pu et al., 2015), genetic variability (Saker et al., 1996) and lifestyle factors (Carroll et al., 2018; Mwanri, Kinabo, Ramaiya, & Feskens, 2014), there are a number of methodological factors influencing prevalence estimation that require consideration. Numerous studies have illustrated the dramatic effect a change in diagnostic criteria can have on the number of women diagnosed with GDM (Adam & Rheeder, 2017; Agarwal, Dhatt, & Othman, 2015; Behboudi-Gandevani et al., 2019; He et al., 2019; Lapertosa et al., 2020; Meloncelli et al., 2020). Even before the point of diagnostic testing, universal compared to risk-factor based screening will have a significant impact on GDM prevalence by altering both the numerator and denominator in calculating the proportion of women with a GDM diagnosis. The timing of screening may also influence prevalence rates. The IADPSG recommend OGTTs are performed between 24 to 28 weeks' gestation, but also suggest a fasting plasma glucose of 5.1 mmol/L or greater at any time in pregnancy could be classified as GDM (International Association of Diabetes and Pregnancy Study Groups Consensus Panel et al., 2010). Others have suggested that while early fasting plasma glucose may be a predictor of later GDM diagnosed at 24 to 28 weeks' gestation, it should not be used as a diagnostic test as not all women with a high early fasting plasma glucose meet criteria for diagnosis of GDM at 24 to 28 weeks' gestation (Corrado et al., 2012; Zhu et al., 2013). Therefore, studies including women diagnosed early in pregnancy will have different prevalence rates to those only diagnosed at 24 to 28 weeks' gestation. The actual uptake of screening and diagnostic testing by women in the population also needs consideration. In a randomised controlled trial involving 23,792 women, Hillier et al. (2021) compared the prevalence of GDM and pregnancy outcomes between women randomised to one-step (75 g-OGTT) screening versus a two-step (50 g glucose challenge test (GCT) followed by 100 g-OGTT if GCT was positive) screening approach. Fewer women in the one-step group compared to the two-step group attended their assigned screening (66% compared to 92% respectively) and GDM prevalence in the one-step approach was almost double that of the two-step approach (16.5% compared to 8.5% respectively) (Hillier et al., 2021). This demonstrates the significant difference screening and diagnostic criteria can have on GDM prevalence.

The data used to calculate prevalence will also have a significant impact on the reported prevalence of a population. The use of population-wide cohort studies to estimate GDM prevalence are impractical and costly. Consequently, either data from smaller cohort studies are extrapolated to the wider population to estimate prevalence statistics or population health datasets are used to estimate

GDM prevalence. Cohort studies vary widely in their methodology in determining GDM prevalence. For example, as well as being subject to the factors influencing prevalence discussed above, decisions to use only women who have data available or all those within a predefined cohort as the denominator will alter the resulting proportion diagnosed with GDM. Different regions within the same country may have significant differences in maternal characteristics, which may result in differences in GDM prevalence across a country (Ministry of Health, 2014). Regional studies may therefore not be generalisable to the rest of the country and will not give an accurate reflection of national GDM prevalence. Diagnosis of GDM according to medical records is frequently cited as a gold-standard data source for estimating the prevalence of GDM within a population (Bell, Ford, Cameron, & Roberts, 2008; Hosler, Nayak, & Radigan, 2010; Lain et al., 2012). However, review of medical records is labour-intensive and relies on the accuracy and description of clinicians' notes. Population health datasets are commonly used as a cost-effective tool for estimating diagnostic statistics. These datasets are derived from coded hospital data extracted from medical records by clinical coders using the International Classification of Diseases (ICD) framework (World Health Organization, 2021) but coding may be subject to varying coding standards and coding errors (O'Malley et al., 2005). Many studies reporting on the validity of population health datasets for ascertaining levels of GDM prevalence claim these datasets provide a reliable source of information on GDM (Baldwin et al., 2021; Taylor, Travis, Pym, Olive, & Henderson-Smart, 2005). However, others highlight limitations and inaccuracies in these datasets (Yapa & Simmons, 2000; Zheng, Morris, & Moses, 2016) and suggest combining datasets or reporting methods would be more accurate (Chen et al., 2012; Devlin et al., 2009; Hadfield et al., 2008; Lain et al., 2012; Lydon-Rochelle, Cárdenas, et al., 2005). A study comparing the prevalence of GDM among women attending a private hospital in New South Wales, Australia according to the New South Wales Perinatal Data Collection and laboratory data found the New South Wales Perinatal Data Collection missed over half of GDM diagnoses according to laboratory data (Zheng et al., 2016). Of those missed, only 53% were documented in the medical notes (Zheng et al., 2016). Furthermore, in a study examining coding data from 7,883 deliveries in Boston, Nicklas et al. (2017) found 34% of GDM of cases coded were coded as such due to clinician documentation in the medical notes but were not substantiated by laboratory data and did not meet diagnostic criteria in established guidelines (Nicklas, Zera, Lui, & Seely, 2017). Together these findings highlight significant limitations in using population health datasets based on coded hospital discharge data and question the validity of considering medical records as a 'gold standard' in GDM prevalence determination. Self-reported data have been suggested to be an accurate alternative data source for estimating the prevalence of GDM within a cohort (Gresham et al., 2015; Hinkle et al., 2017; Hosler et al., 2010). However, the validity of these claims are highly dependent on the data source used to determine the

level of agreement and may vary depending on the timing and method of self-reported data collection (Gresham et al., 2015; Hinkle et al., 2017). Some have compared self-reported data to birth data (Gresham et al., 2015; Hosler et al., 2010) which have been demonstrated by others to be inferior to hospital discharge data (Lain et al., 2012; Lydon-Rochelle, Holt, et al., 2005). Others compare self-reported data to medical notes (Hinkle et al., 2017) which are subject to the inaccuracies described above.

In New Zealand, reports of GDM prevalence are limited to small cohort studies from defined geographical areas (Chepulis et al., 2020; Daly, Raiman, & Goodson, 2017; Ekeroma et al., 2015; Reddy, 2006; Yapa & Simmons, 2000), single organisation reports (National Women's Health, 2021; Waikato District Health Board, 2015), or outdated coding data reported by region (Ministry of Health, 2014). Estimates of GDM prevalence in New Zealand range from 1.4 – 13.1% (Ministry of Health, 2014; National Women's Health, 2021) with a trend of increasing prevalence over time (National Women's Health, 2021; Winnard, Anderson, MacLennan, Okesene-Gafa, 2013). As mentioned, universal screening for GDM is recommended at 24 to 28 weeks' gestation either with a GCT or OGTT dependent upon early pregnancy HbA1c result (Ministry of Health, 2014). However, screening rates are variable and disproportionately implemented across ethnic groups (Chepulis et al., 2020; Daly et al., 2017; Ekeroma et al., 2015; Simmons, Rowan, Reid, Campbell, & on behalf of the National GDM Working Party, 2008; Winnard, Anderson, MacLennan, Okesene-Gafa, 2013). A recent review of clinical records of all women without a pre-pregnancy diagnosis of diabetes in Waikato showed poor adherence to screening guidelines with only 33% of women undergoing a GCT or OGTT at 24 to 28 weeks' gestation as recommended by national guidelines (Chepulis et al., 2020; Ministry of Health, 2014). Significant differences in screening rates according to ethnicity were also seen. Despite Māori women's greater predisposition to developing GDM (Yapa & Simmons, 2000), significantly fewer Māori women were screened compared to non-Māori (Chepulis et al., 2020). Similarly, an audit of routinely collected hospital data in the Bay of Plenty found only 63% of women were screened for diabetes in pregnancy and, again, significantly fewer Māori women were screened compared to women of European ethnicity (Daly et al., 2017). These findings illustrate the difficulties faced in determining the true prevalence of GDM, not only in New Zealand but internationally, adding to the challenge of providing appropriate services in order to best meet the needs of women with GDM.

Management of GDM

The aim of GDM treatment is to maintain blood glucose concentrations as close as possible to normoglycaemia to reduce the risk of complications for both mother and infant during pregnancy and

in later life. Management of GDM typically constitutes self-monitoring of blood glucose concentrations, diet, physical activity and pharmacological treatment with oral hypoglycaemic agents or insulin where diet and physical activity have not been effective in achieving blood glucose targets (Farrar et al., 2017). Diet is considered the cornerstone of management of GDM and dietary advice is recommended as the first-line strategy for treatment (American Diabetes Association, 2020; Duarte-Gardea et al., 2018; Feig et al., 2018; Hod et al., 2015; Ministry of Health, 2014; National Institute for Health and Care Excellence, 2015). Physical activity is frequently recommended as an adjunct to dietary adaptations and most women can be successfully managed with diet and physical activity modifications alone (Ducarme et al., 2019; McFarland, Langer, Conway, & Berkus, 1999; Sun et al., 2020; Tang, Xu, Li, & Li, 2019). Two large randomised controlled trials have found treatment of mild hyperglycaemia in pregnancy (women with impaired glucose tolerance not meeting diagnostic thresholds for GDM) with diet and lifestyle advice and insulin where required, to be associated with improved health outcomes for both mother and infant when compared to women receiving standard care (Crowther et al., 2005; Landon et al., 2009). Women in the treatment groups had lower gestational weight gain, lower incidence of pre-eclampsia or gestational hypertension and lower incidence of shoulder dystocia and large-for-gestational-age infants. In a Cochrane overview of treatments for GDM, Martis et al. (2018) found lifestyle interventions (including healthy eating, physical activity and self-monitoring of blood glucose) to be the only intervention that showed possible health benefits for women and infants (Martis, Crowther, et al., 2018). A number of trials have compared modified diets or intensified dietary advice with standard diet and lifestyle advice for women with GDM (Asemi et al., 2013, 2014; Hu et al., 2014; Louie et al., 2011; Ma et al., 2015; Moreno-Castilla et al., 2013; Moses et al., 2009; Wang et al., 2015; Yao et al., 2015) but many are limited by small sample sizes and pooling of results are limited by heterogeneity (Farrar et al., 2017; Han, Middleton, Shepherd, van Ryswyk, & Crowther, 2017; Yamamoto et al., 2018). For example, studies include different outcomes in their analyses, have different inclusion and exclusion criteria, varying frequency and delivery of dietary counselling, intervention duration, differences in determining level of compliance to the prescribed regime and different criteria to commence insulin. This makes it difficult to ascertain whether differences in outcomes are due to dietary modifications or differences in other aspects of the intervention (Farrar et al., 2017; Han et al., 2017; Yamamoto et al., 2018; Yao et al., 2015). Although most of these interventions appear to result in favourable outcomes, particularly in terms of glycaemic control and infant birth weight, strong evidence is lacking (Yamamoto et al., 2018). Whether there is a specific diet that is most effective for the management of GDM for both short and long-term outcomes remains unclear (Farrar et al., 2017; Han et al., 2017; Martis, Crowther, et al., 2018; Mitanchez, Ciangura, & Jacqueminet, 2020; Yamamoto et al., 2018).

In a systematic review, Mustafa et al. (2021) appraised the quality of clinical practice guidelines for the management of GDM with a focus on the strength and evidence base behind dietary recommendations (Mustafa, Hofer, Harding, Wall, & Crowther, 2021). Of 31 clinical practice guidelines identified, only 3 were considered to be of high quality. A total of 313 dietary recommendations for women with GDM were identified within the 31 guidelines, with the authors reporting that the majority are based on very low-quality evidence (Mustafa et al., 2021). However, a variety of assessment tools were used to evaluate the evidence behind recommendations within the guidelines, the applicability of which have been questioned in relation to nutrition evidence, given the observational nature of many nutrition studies (Tobias, Wittenbecher, & Hu, 2021). Key diet and lifestyle recommendations made by major clinical practice guidelines are summarised in Table 2. Despite variability in some recommendations, key messages from the major clinical practice guidelines are consistent. Most recommend distribution of carbohydrate intake across the day, replacing high glycaemic index foods with those with a low glycaemic index, consuming a minimum of 175 g carbohydrate per day, encouraging regular physical activity and otherwise ensuring adequate nutrition for maternal and fetal growth and development (Mustafa et al., 2021). Major clinical practice guidelines are unanimous in recommending that women with GDM receive this diet and lifestyle advice from a dietitian.

Dietetic management of GDM

Dietitians are health professionals who evaluate scientific evidence about food and nutrition and translate it into practical strategies to help people improve their health and lifestyle through optimal nutrition (Dietitians Board, 2021). Medical nutrition therapy (MNT) is defined as "the use of specific nutrition services to treat an illness, injury or condition" (Pastors, Warshaw, Daly, Franz, & Kulkarni, 2002) and is typically delivered by a dietitian. MNT in GDM aims to meet the nutritional requirements of pregnancy for the birth of a healthy infant and promote maternal health, whilst maintaining normal glycaemia and appropriate gestational weight gain in order to reduce the complications associated with GDM (Duarte-Gardea et al., 2018). Nutrition education delivered during pregnancy could also promote health behaviours that extend beyond pregnancy, with protective effects against the long-term consequences of GDM such as type 2 diabetes for both mother and infant (Moreno-Castilla, Mauricio, & Hernandez, 2016). The Academy of Nutrition and Dietetics recommend that

Table 2. Summary of key clinical practice guideline diet and lifestyle recommendations for the management of GDM

Clinical practice guideline	First-line therapy	Health-professional to provide advice	Key recommendations	Frequency of input
American Academy of Nutrition and Dietetics (Duarte-Gardea et al., 2018)	MNT and physical activity	Dietitian	Minimum of 175 g CHO, 71 g protein (or 1.1 g/kg/d protein) and 28 g fibre. Amount and type of CHO should be individualised. Distribute of CHO into 3 meals and ≥ 2 snacks. FDA approved high-intensity sweeteners safe when limited to the ADI. Encourage daily moderate intensity exercise of ≥30 minutes.	At least three consultations with a dietitian
American Diabetes Association (American Diabetes Association, 2020)	MNT, physical activity and weight management	Dietitian	Provide adequate calories to promote fetal/neonatal and maternal health, achieve glycaemic goals and promote appropriate GWG. Minimum of 175 g CHO, 71 g protein and 28 g fibre.	NA
Canadian Diabetes Association (Feig et al., 2018)	Diet and physical activity	Dietitian	Promote adequate nutritional intake without ketosis to achieve glycaemic goals, appropriate fetal growth and maternal weight gain. Weight gain according to IOM guidelines. Minimum 175 g CHO per day distributed over 3 meals and ≥ 2 snacks. Replace high-GI with low-GI foods. Encourage physical activity.	NA
Diabetes United Kingdom (Dyson et al., 2018)	Diet and physical activity	Dietitian	Aim to achieve appropriate weight gain. Regular physical activity including 30 minutes walking after a meal.	NA
International Federation of Gynecology and Obstetrics (Hod et al., 2015)	Diet and physical activity	Dietitian	Caloric intake based on pre-pregnancy BMI and desirable weight gain (35 – 40 kcal/kg for underweight, 30 – 45 kcal/kg for normal weight, 25 – 30 kcal/kg for overweight women. For obese women calorie intake can be reduced by 30% but not below 1600 – 1800 kcal/day). Limit CHO intake to 35 – 45% total calories. Minimum 175 g CHO per day distributed over 3 meals and 2 to 4 snacks. Up to 28 g fibre per day. Physical activity of 30 minutes per day, brisk walking or seated	Routine follow-up throughout pregnancy to achieve and maintain treatment goals.

			arm exercised for 10 minutes after each meal. Encourage continuation of healthy eating habits postnatally.	
New Zealand Ministry of Health (Ministry of Health, 2014)	Diet and lifestyle advice (includes physical activity)	Dietitian	Individualised meal plans incorporating lifestyle and cultural factors. Energy intake should be no less than 1800 kcal/day. Spread CHO evenly throughout the day between meals and snacks. Minimum 175 g CHO per day. Reduce intake of saturated fats. Consume lean protein. GWG in line with Ministry of Health (2014) recommendations. Reduce risk of subsequent GDM or T2DM by maintaining healthy diet, increasing physical activity and weight loss in those who are overweight or obese.	Initiate treatment as soon as possible after diagnosis.
National Institute for Health and Care Excellence (National Institute for Health and Care Excellence, 2015)	Diet and physical activity	Dietitian	Foods with low-GI should replace those with high-GI. Regular physical activity. Offer postnatal lifestyle advice.	First appointment within 1 week of diagnosis and then every 1 – 2 weeks throughout pregnancy with joint diabetes and antenatal clinic
Queensland Health (Queensland Clinical Guidelines, 2021)	Diet and physical activity	Dietitian	Culturally appropriate, individualised dietary advice to achieve optimal nutrition for maternal and fetal health, appropriate GWG, BGLs within target range and an absence of ketones. CHO spread evenly and tailored to individual needs. Minimum of 175 g CHO per day. Low GI diet. Recommend 30 minutes of physical activity on most days of the week.	Refer to a dietitian within one week of diagnosis and offer at least 3 appointments with additional reviews as clinically needed and one postnatal follow-up appointment.

ADI Acceptable daily intake, *GDM* gestational diabetes mellitus, *T2DM* type 2 diabetes, *BGLs* Blood glucose levels, *BMI* Body Mass Index, *CHO* carbohydrate, *FDA* Food and Drug Administration, *GI* glycaemic index, *GWG* gestational weight gain, *IOM* Institute of Medicine, *MNT* Medical Nutrition Therapy

women with GDM be seen by a dietitian at least three times during their pregnancy (Duarte-Gardea et al., 2018). These recommendations were validated in a multicentre randomised trial in which 25 sites were randomised to follow nutrition practice guidelines or usual care (Reader, Splett, Gunderson for the Diabetes Care and Education Dietetic Practice Group, 2006). Data from 215 women demonstrated significantly lower insulin use in obstetric clinic sites following the nutrition practice guidelines and improvements in HbA1c and perinatal outcomes (Reader et al., 2006). Early management of GDM and regular contact with a dietitian have been associated with changes in energy intake and macronutrient balance (Morisset et al., 2014), lower gestational weight gain (Garduño-Alanis et al., 2020; Morisset et al., 2014), and reduced incidence of macrosomia (Shushan, Ezra, & Samueloff, 1997).

A schedule of regular consultations with a dietitian initiated soon after diagnosis with GDM is considered by some as best practice in the dietary management of GDM (Wilkinson, McCray, Beckmann, & McIntyre, 2016). However, whilst there is a consistent trend in increasing prevalence of GDM, resource allocation for managing GDM has not matched these increases (Meloncelli, Barnett, & de Jersey, 2020; Sina et al., 2020). Staff resourcing and availability of clinic space is often cited as a barrier to providing care according to practice recommendations (Meloncelli et al., 2020; Wilkinson, McCray, Kempe, & Sellwood, 2018). In a survey of 220 dietitians in Australia, Morrison et al. (2011) reported only 54% of dietitians believed that their service offered adequate dietetic intervention for women with GDM and half reported dietetic staffing levels to influence the frequency of dietetic input (Morrison, Collins, & Lowe, 2011). Provision of group education sessions as a means for initial education for newly diagnosed women with GDM is a strategy commonly used to accommodate increasing numbers of women diagnosed with GDM within the context of limited resources (Flack, Ross, Ho, & McElduff, 2011; Sina et al., 2020). In a study by Barnes et al. (2018) including 362 women with GDM attending a group education session and 381 women attending individual dietetic appointments, significantly more women attending group sessions required insulin therapy in addition to MNT compared to women receiving individual appointments (Barnes, Ross, Jalaludin, & Flack, 2018). Wamae et al. (2015) also reported a lower proportion of women requiring medication to manage GDM in those attending one-on-one sessions with a dietitian compared to those attending group sessions in a study of 136 women with GDM in London (Wamae, Howard, Khan, & Ajala, 2015). Despite the saving in dietetic clinical time associated with group sessions, the authors concluded that group education sessions should not be a stand-alone education method for women with GDM and that the additional cost of dietetic time may be offset by cost-savings in reduced insulin requirements in those receiving individual initial appointments (Barnes et al., 2018). Barnes et al. (2018) also found attendance rates to be significantly lower for the group sessions compared to individual appointments (Barnes et al., 2018). This perhaps indicates that women have a preference for, or place greater value on, individual appointments with a dietitian.

Lack of awareness of the benefits of dietetic input in GDM (Meloncelli, Barnett, Pelly, & de Jersey, 2019; Wilkinson, McCray, Beckmann, Parry, & McIntyre, 2014) may be a contributing factor to the considerable variation in the management of GDM reported in the literature (Farhanah, Fatin Nasirah, Barakatun Nisak, Nor Azlin, & Zalilah, 2014; Meloncelli et al., 2019; Morrison et al., 2011). In a survey of 183 health professionals involved in the management of women with GDM in Australia, Meloncelli et al. (2019) found that only 63% of healthcare professionals used guidelines for the management of GDM, and blood glucose targets and criteria for the commencement of pharmacotherapy varied among respondents. Although 82% of respondents reported MNT to be considered a first-line treatment for GDM, a third of respondents suggested this could be delivered by any member of the multidisciplinary team (Meloncelli et al., 2019). Similarly, in surveys of 44 multidisciplinary staff, Wilkinson et al. (2014) found that whilst most staff believed regular contact with a dietitian could influence diet, gestational weight gain and macrosomia, fewer believed dietetic consultation could influence blood glucose levels, requirements for pharmacotherapy and care costs (Meloncelli et al., 2019; Wilkinson et al., 2014).

These findings are also reflected in two surveys of dietetic practice conducted in Australia and Malaysia (Farhanah et al., 2014; Morrison et al., 2011). In a survey of 220 dietitians in Australia, only 77% reported that all women with GDM were referred for dietetic input (Morrison et al., 2011). Furthermore, approximately a third of women with GDM in Australia (Morrison et al., 2011) and almost two thirds of women in Malaysia (Farhanah et al., 2014) received preliminary nutrition information prior to their first appointment with the dietitian. Inconsistencies in recommendations relating to suggested macronutrient distributions and use of the glycaemic index were reported in both surveys (Farhanah et al., 2014; Morrison et al., 2011). Whilst some variation in content could be expected due to individualisation of MNT, some of the recommendations reported, or lack thereof, are not consistent with the evidence available. For example, only 40% of dietitians in the survey by Morrison et al. (2011) provided weight gain targets for women with GDM, despite evidence of the influence of gestational weight gain on pregnancy outcomes (Aiken, Hone, Murphy, & Meek, 2019; Barnes et al., 2020; Institute of Medicine & National Research Council, 2009). In the same survey, dietitians reported recommending a minimum carbohydrate intake ranging from 60 to 300 g per day (Morrison et al., 2011). Although there is no nutrient reference value for carbohydrate during pregnancy in Australia or New Zealand (National Health and Medical Research Council; Ministry of Health, 2006), the IOM recommended dietary allowance for carbohydrate is 175 g per day for pregnant women (Institute of Medicine, 2005). This was calculated to be the minimum required amount in order to allow sufficient glucose for adequate fetal brain utilisation in 97 – 98% of pregnant women (Institute of Medicine, 2005). Application of evidence-based practice is essential for the provision of high-quality patient care and dietitians are expected to apply valid and current research findings in their clinical practice (Byham-Gray, Gilbride, Dixon, & Stage, 2005). Twenty-one percent of Australian dietitians reported using service-specific practice guidelines for the management of GDM and only half used guidelines on macro- and micronutrient content of the diet in the management of GDM (Morrison et

al., 2011). The authors of both dietetic surveys suggest a need for locally relevant nutrition practice guidelines for the management of GDM (Farhanah et al., 2014; Morrison et al., 2011). Utilisation of evidence-based practice guidelines may also improve the consistency of MNT delivered. This is especially important for pregnant women as women receive information on diet from a range of sources during pregnancy, some which may be conflicting and lead to confusion, frustration and a lack of trust in the information provided (Carpenter et al., 2016; Schölmerich, Ghorashi, Denktaş, & Groenewegen, 2016). Consistent messages about nutrition are therefore paramount to instilling trust in the advice provided by healthcare professionals. How GDM is managed by dietitians in New Zealand has not been previously reported.

Women's perceptions of dietary management of GDM

Whilst health outcomes and the costs associated with GDM management are vitally important, how women perceive the management of GDM requires equal consideration as this is likely to be a significant factor in women's behaviour in managing GDM and their long-term health. Given the diagnosis of GDM is usually made at 24 to 28 weeks' gestation (Ministry of Health, 2014), women who develop GDM are presented with the challenge of learning how to manage their condition within a short time-frame in order to ameliorate associated risks for themselves and their baby. For many, this requires increased antenatal visits, dietary adaptations, increasing physical activity, self-monitoring blood glucose levels and, for some, the administration of insulin. The complexity of this and the urgency to master the self-management of GDM is frequently described by women as overwhelming (He, Chen, Wang, Liu, & Bai, 2020; Neufeld, 2011; Oster, Mayan, & Toth, 2014; Yee, McGuire, Taylor, Niznik, & Simon, 2016). Qualitative studies exploring women's experiences of GDM have found many women wished they had received information on how to reduce their risk of GDM or how to best manage GDM earlier (Hjelm, Berntorp, Frid, Aberg, & Apelqvist, 2008; Hjelm, Bard, Nyberg, & Apelqvist, 2007; Parsons et al., 2018; Razee et al., 2010; Wah et al., 2019). In a focus group study involving 19 women with GDM in the United Kingdom, Draffin et al. (2016) reported that some women expressed anger at their healthcare professional for not advising them to lose weight prior to conception in order to reduce their risk of developing GDM (Draffin et al., 2016). Once diagnosed with GDM, a delay in receiving advice from healthcare professionals can lead to increased anxiety and may mean women resort to searching for information from other, potentially less credible, sources (Draffin et al., 2016; Hjelm et al., 2008; Hjelm et al., 2007). Women also reported seeking alternative sources of information or dismissing information provided from healthcare professionals (Doran, 2008; Draffin et al., 2016; Lawson & Rajaram, 1994; Neufeld, 2010; Yee et al., 2016) when they felt healthcare professionals lacked sufficient nutrition knowledge to guide them appropriately (Doran, 2008; Lawson & Rajaram, 1994).

Dietary management of GDM requires understanding and knowledge of different food types and of appropriate quantities to eat, exercise and motivation (Carolan, 2013). Women with GDM have described dietary advice to

be complex (Draffin et al., 2016; Oster et al., 2014), challenging and unrealistic to fit into their lifestyle (Neufeld, 2011; Yee et al., 2016). Many women report a lack of culturally appropriate or individually tailored dietary advice (Bandyopadhyay et al., 2011; Bandyopadhyay, 2021; Draffin et al., 2016; Kaptein et al., 2015; Yee et al., 2016). In a focus group study of 29 healthcare professionals' experiences in managing women with diabetes in pregnancy, healthcare professionals themselves expressed a lack of awareness of cultural diets and limited availability of culturally sensitive educational materials (Yee, Leziak, Jackson, Niznik, & Simon, 2020). Women from ethnic minorities tend to experience the highest prevalence of GDM (Berkowitz et al., 1992; Hedderson, Darbinian, et al., 2010) and often face additional challenges in managing their condition. Women from different cultural backgrounds frequently report dietary recommendations to be very different from their cultural diet, making it difficult to adapt their diet accordingly (Bandyopadhyay et al., 2011; Bandyopadhyay, 2021; Collier et al., 2011; Kaptein et al., 2015; Neufeld, 2011; Yee et al., 2016). In a qualitative study involving face-to-face interviews with 17 immigrant South Asian women in Australia, Bandyopadhyay et al. (2011) described women from South Asian backgrounds feeling caught between different cultural concepts of health during pregnancy. Women reported advice on diet and exercise for the management of GDM conflicted with their cultural beliefs (Bandyopadhyay et al., 2011). Women also reported difficulty in describing traditional foods and preparation methods to the dietitian which led to dissatisfaction with their encounter (Bandyopadhyay et al., 2011). Similar findings were reported by Draffin et al. (2016) in which women expressed a desire to speak with someone who was familiar with their cultural diet (Draffin et al., 2016). Several studies report women to express limited comprehension of the dietary changes required to manage GDM (Carolan, Gill, & Steele, 2012; Carolan-Olah, Duarte-Gardea, Lechuga, & Salinas-Lopez, 2017; Ge, Wikby, & Rask, 2016b; Neufeld, 2011). For example, in a qualitative study involving 15 women with GDM recruited from a socially disadvantaged area in Melbourne, Carolan et al. (2012) reported women lacked understanding of what they needed to do practically to control their blood glucose levels (Carolan et al., 2012). Women described receiving general dietary guidelines but insufficient information on how to implement the necessary changes (Carolan et al., 2012; Yee et al., 2016). In an earlier study surveying 143 women with GDM, Carolan et al. (2010) found women from ethnic minorities to be at greater risk of poor self-management of GDM due to lower health literacy and lower appreciation of GDM as a serious condition (Carolan, Steele, & Margetts, 2010). Similar findings are seen in other studies involving ethnic minorities (Carolan-Olah et al., 2017; Hjelm, Bard, Nyberg, & Apelqvist, 2005; Hjelm, Berntorp, & Apelqvist, 2012; Rhoads-Baeza & Reis, 2012) including a study in New Zealand (Workbase Education Trust, 2014). The Workbase Education Trust conducted interviews with 22 Māori and Pacific recently pregnant women and found that a number of women did not undergo screening for GDM as they did not feel that this was important (Workbase Education Trust, 2014). Those women who did undergo screening described a positive relationship with their lead maternity carer who had explained the consequences of untreated GDM, why they were at risk and what screening involved (Workbase Education Trust, 2014). This demonstrates how the nature of the relationship with the healthcare professional, not just the information provided, can influence a women's management of GDM.

Several qualitative studies have described women feeling blamed for developing GDM and feeling lectured or reprimanded when they have difficulty conforming to recommendations (Evans & O'Brien, 2005; Neufeld, 2010; Nolan, McCrone, & Chertok, 2011; Oster et al., 2014). Other women found healthcare professionals to be condescending when giving dietary advice that they were already aware of (Neufeld, 2010; Nolan et al., 2011). Many studies report pregnancy to be tainted with negativity as diabetes becomes the focus of medical attention rather than pregnancy itself (Anderberg, Berntorp, & Crang-Svalenius, 2009; Lawson & Rajaram, 1994; Martis, Brown, McAra-Couper, & Crowther, 2018). Women in the study by Hjelm et al. (2008) expressed a desire for a more holistic approach to their care with greater cooperation between the diabetes team responsible for managing their GDM and the midwife caring for their pregnancy (Hjelm et al., 2008). This is mirrored in other studies where women report their care to lack continuity (Ge et al., 2016b) and report receiving conflicting advice from different healthcare practitioners (Draffin et al., 2016; Neufeld, 2010).

Despite these difficulties, a consistent theme is the woman's desire to protect the health of her unborn baby. This acts as a strong motivator to manage GDM (Carolan et al., 2012; Carolan-Olah et al., 2017; Devsam, Bogossian, & Peacock, 2013; Martis, Brown, et al., 2018). Women frequently report fear and guilt at the thought of negatively affecting their baby's health (Carolan et al., 2012; Carolan-Olah et al., 2017; Oster et al., 2014) and are willing to make the necessary changes to their diet and lifestyle to benefit the health of their baby (Bandyopadhyay et al., 2011; Carolan et al., 2012). Psychological support from families and health professionals are reported to be strong enablers to compliance and self-efficacy in the management of GDM (Carolan et al., 2012; Kim, Cho, & Shin, 2021; Lapolla et al., 2012; Oster et al., 2014; Persson, Winkvist, & Mogren, 2010; Symons Downs & Ulbrecht, 2006; Wah et al., 2019). In a survey of 28 women with GDM in the United States, a woman's partner or husband was identified to have the strongest influence on physical activity during pregnancy (Symons Downs & Ulbrecht, 2006). Women also view healthcare professionals as a source of support not only in terms of improving their comprehension of how to manage their condition (Carolan et al., 2012; Hjelm et al., 2012) but also as emotional support through listening and understanding (Hjelm et al., 2012; Oster et al., 2014). Some women have reported viewing the diagnosis of GDM positively and describe it as a 'wake-up call' and opportunity to improve their long-term health and reduce the risk of developing type 2 diabetes in the future (Carolan et al., 2012; Carolan-Olah et al., 2017; Doran, 2008; Evans & O'brien, 2005; Neufeld, 2011; Nolan et al., 2011). In unstructured interviews, women with GDM reported using the knowledge they gained through having diabetes in pregnancy to lead a healthier life after pregnancy and act as a role model for their families (Oster et al., 2014).

Whilst two studies have described different aspects of women's experiences of GDM in New Zealand (Martis, Brown, & Crowther, 2017; Reid, Anderson, Cormack, Reid, & Harwood, 2018), there remains a lack of understanding of how women perceive dietary advice for the management of GDM and how this influences

their dietary behaviours. An understanding of how women with GDM experience dietary advice provided by dietitians and other healthcare professionals may facilitate greater support for women with GDM to optimise the management of their condition and long-term health.

Research aims

The overall purpose of this thesis is to describe the diets and dietary management of women with GDM in New Zealand. Four research studies explored difference aspects to this with specific research objectives listed in Table 3.

Table 3. Research objectives

Study	Research objectives	Associated publications
Study 1: Estimation of the prevalence of GDM in New Zealand (Chapter 2)	1.1 Determine the prevalence of GDM in a cohort of New Zealand women using a variety of data sources. 1.2 Evaluate the level of agreement between different data sources.	Lawrence RL, Wall CR, Bloomfield FH. Prevalence of gestational diabetes according to commonly used data sources: an observational study. *BMC Pregnancy and Childbirth* 2019; **19**(1):349-358
Study 2: Description of the diets of pregnant women with and without GDM in New Zealand (Chapter 3)	2.1 Explore differences in diet between women with and without GDM in New Zealand including differences in: 2.1.1 Adherence to the Ministry of Health's Food and Nutrition Guidelines for Healthy Pregnant and Breastfeeding Women 2.1.2 Dietary patterns 2.1.3 Dietary adaptations 2.1.4 Sources of dietary information leading to dietary change 2.2 Determine whether there is a dietary pattern that is associated with an increased or decreased risk of developing GDM. 2.3 Determine whether adherence to the Ministry of Health's Food and Nutrition Guidelines for Healthy Pregnant and Breastfeeding Women is related to risk of developing GDM.	Lawrence RL, Wall CR, Bloomfield FH. Dietary patterns and dietary adaptations in women with and without gestational diabetes: Evidence from the Growing Up in New Zealand Study. *Nutrients* 2020; **12**(1):227-242 Lawrence RL, Wall CR, Bloomfield FH. Adherence to food and nutrition guidelines among women with and without gestational diabetes: Evidence from the Growing Up in New Zealand Study. *Nutrients* 2022; **14**(10):2145
Study 3: Dietetic management of GDM in New Zealand (Chapter 4)	3.1 Establish what dietetic services are provided for women with GDM in New Zealand. 3.2 Evaluate current dietetic practice in the management of GDM, compare this to evidence-based practice guidelines. 3.3 Determine the perceived need for New Zealand specific evidence-based guidelines for the nutritional management of GDM.	Lawrence RL, Wall CR, Bloomfield FH, Crowther CA. Dietetic management of gestational diabetes in New Zealand: A cross-sectional study. *Nutrition & Dietetics* 2016; **73**(5):95-104
Study 4: Women's experiences of managing gestational diabetes through diet (Chapter 5)	4.1 Explore how women diagnosed with GDM perceive dietary recommendations. 4.2 Explore how this information influences their dietary decisions during pregnancy and beyond.	Lawrence RL, Ward K, Wall CR, Bloomfield FH. New Zealand women's experiences of managing gestational diabetes through diet: A qualitative study. *BMC Pregnancy and Childbirth* 2021; **21**(1):1-12

Chapter 2

Estimation of the prevalence of GDM in New Zealand

This chapter has been published as a peer review journal article:

Lawrence RL, Wall CR, Bloomfield FH. (2019). Prevalence of gestational diabetes according to commonly used data sources: An observational study. *BMC Pregnancy and Childbirth* 19(1): 349 – 358

Prevalence of gestational diabetes according to commonly used data sources: an observational study

Introduction

GDM is frequently described as the most common metabolic disorder of pregnancy with prevalence increasing at epidemic proportions (Dabelea et al., 2005; Koo, Lee, Kim, Jang, & Lee, 2016; Lavery, Friedman, Keyes, Wright, & Ananth, 2016). However, reported prevalence worldwide varies between 1 – 45% of pregnancies (Agarwal et al., 2015; Buckley et al., 2012). While there are some clear reasons for this variability, others are not as obvious. Different ethnicities have different susceptibility to GDM; therefore, differences in the ethnic make-up of the population studied as well as genetic variability will result in different prevalence rates of GDM (Pu et al., 2015; Saker et al., 1996; Savitz et al., 2008; Solomon et al., 1997). Similarly, the lack of consensus in which diagnostic threshold should be used to diagnose GDM results in variation in prevalence (Agarwal et al., 2015; Berggren, Boggess, Stuebe, & Jonsson Funk, 2011; Djelmis et al., 2016; Ekeroma et al., 2015). An issue that is less frequently considered is the data source used to calculate prevalence. Population-wide cohort studies are impractical and costly; therefore, smaller cohort studies are often used to extrapolate estimates of GDM prevalence to the wider population. However, differences in the type of data used to calculate prevalence may lead to substantial differences in the reporting of GDM prevalence (Lawrence, 2010; Pedersen, Olesen, Jorgensen, & Damm, 2016). For example, a cohort consisting of a population of women who were screened for GDM will have a smaller denominator than a cohort including all pregnant women in a given hospital in which screening of all women is not routine (Alberico et al., 2004; Pedersen et al., 2016; Simmons, Devers, Wolmarans, & Johnson, 2009). Accurate estimation of GDM prevalence is important for service planning, funding allocation, and research. Inaccurate estimates, or varied estimates within a health service due to different methodologies, may result in inequitable or inadequate care.

The prevalence of GDM in New Zealand is not definitively known and reports in the literature are from small studies in small catchment areas, with varying methodology (Daly et al., 2017; Ekeroma et al., 2015; McGrath, Baker, & Simkins, 2014; National Women's Health, 2018; Winnard, Anderson, MacLennan, Okesene-Gafa, 2013; Yapa & Simmons, 2000). The GUiNZ study is a large, ongoing, longitudinal cohort study which recruited pregnant women living within a geographical area serviced by three neighbouring regional health boards: Auckland (ADHB); Counties Manukau (CMDHB), and Waikato (WDHB) District Health Boards (DHBs), which account for almost a third of New Zealand's population (Morton et al., 2013). This geographical area was selected to provide a diverse birth cohort that would be broadly generalisable to New Zealand births (Morton et al., 2013). The aim of this study was to determine the prevalence of GDM in GUiNZ study as a whole and according to the data source used. Prevalence of GDM in the GUiNZ study was then compared to prevalence according to the Ministry of Health's National Minimum Dataset.

Methods

Data for the primary analyses in this study were derived from the GUiNZ longitudinal study cohort, described in detail elsewhere (Morton et al., 2013). Briefly, pregnant women estimated to birth between 25th April 2009 and 25th March 2010 and living within the geographical boundaries serviced by ADHB, CMDHB and WDHB, were invited to participate in the study. Place of residence was the only inclusion criterion and there were no exclusion criteria (Morton et al., 2013). The need for a new birth cohort study in New Zealand was identified by the New Zealand Ministry of Social Development, which is the lead agency responsible for its commissioning and funding but which had no other role in conducting the research or in writing this manuscript. Ethical approval was obtained from the Ministry of Health Northern Y Regional Ethics Committee and written informed consent was obtained from all participating women. A total of 6,822 women consented and completed the antenatal interview. Birth characteristics of the GUiNZ cohort were comparable to national birth statistics at that time (Morton et al., 2015).

Data sources for identification of GDM

Four data sources were used to identify cases of GDM within the cohort: coded clinical data held by the three DHBs within the study catchment area; coded clinical data held by the Ministry of Health's National Minimum Data set; blood results including fasting plasma glucose concentration, GCT results and OGTT obtained from laboratories servicing the recruitment catchment area; and participant self-report in the GUiNZ antenatal and 16-month post-partum interviews. Linking to routine health records was available for women who consented to this using their unique National Health Identifier (NHI) (n=6,657). Participants' NHIs were used to extract coding data held by DHBs and the Ministry of Health's National Minimum Data set and blood results from laboratories servicing the recruitment catchment area. The Ministry of Health and CMDHB provided coding information according to the International Classification of Diseases (ICD) 10 codes extracted from the National Minimum Dataset and hospital-wide database respectively. ADHB and WDHB provided codes as normal glucose tolerance, gestational diabetes, pre-existing type 1 diabetes, pre-existing type 2 diabetes or impaired glucose tolerance extracted from their local maternity database and diabetes clinic database respectively. Women were further coded as having GDM if they had a positive blood glucose result (at any time from 12 weeks' gestation up until birth) according to the diagnostic criteria for GDM in use by their DHB of domicile at the time. All three DHBs in the GUiNZ study used the New Zealand Society for the Study of Diabetes criteria (New Zealand Society for the Study of Diabetes, 1995; Simmons et al., 2006) from a 75 g-OGTT to diagnose GDM: fasting plasma glucose ≥5.5 mmol/L or a 2-hour plasma glucose ≥ 9.0 mmol/L (National Women's Health, 2010, 2011; Winnard, Anderson, MacLennan, Okesene-Gafa, 2013, Jade Tamatea, Endocrinologist, WDHB, emailed personal communication, April 27, 2017). In addition, CMDHB utilised an additional screening test, a 50 g-GCT with a single 60-minute plasma glucose sample. If the result of this 60-minute sample was a plasma glucose concentration ≥11.1 mmol/L, this was considered diagnostic of gestational diabetes without confirmation with the standard 2-hour, 75 g-OGTT (Winnard, Anderson, MacLennan, Okesene-Gafa, 2013).

Women with a plasma glucose concentrations <11.1 mmol/L but ≥7.8 mmol/L at 60 minutes proceeded to a standard 75 g-OGTT as detailed above. The pregnancy period was calculated for each woman using documented length of gestation and date of delivery. Where no length of gestation was available, 40 weeks was used as proxy (n=905). Responses to the GUiNZ antenatal and 16-month post-partum interviews were used to collate self-reported data on diabetes in pregnancy status. Participants were asked about their diabetes status in pregnancy at two time points. First, during a face-to-face computer-assisted personal interview during pregnancy (most frequently early in the third trimester) in which women were asked "Have you ever had diabetes?" with possible responses being "never", "before this pregnancy but not during this pregnancy", "before this pregnancy and during this pregnancy", "only during this current pregnancy" and "don't know". Women were then asked again 16 months after the birth of their child(ren) in a computer-assisted telephone interview: "Thinking about the last 14 weeks of your pregnancy with [name], during this time were you diagnosed with diabetes – this would be where your doctor, midwife, or other lead maternity carer told you that you had diabetes for the first time?" Possible responses included "yes", "no," "don't know". Women who responded "only during this current pregnancy" to the first question and/or "yes" to the second question were coded as having GDM according to self-reported data. Women who had a previous pregnancy and responded "before and during this pregnancy" and "yes" to the second question were also coded as having GDM with the assumption that there was GDM in the index pregnancy and a history of GDM in a previous pregnancy. Women were coded as having GDM if they met the criteria for GDM in their DHB according to any data source. If inconsistencies were present in the type of diabetes between data sources, the most recent DHB or Ministry of Health coding data were used.

The antenatal interview also included questions about maternal socio-demographic, health, and lifestyle characteristics. Following the coding criteria used by Statistics New Zealand, self-reported ethnicity was assigned to one of six Level 1 categories: (i) European; (ii) Māori; (iii) Pacific Peoples; (iv) Asian; (v) Middle Eastern / Latin American / African (MELAA), and (vi) Other ethnicity (Statistics New Zealand, 2005). If women identified with more than one ethnicity and did not self-prioritised a primary ethnicity, prioritisation was determined following the methodology of Statistics New Zealand in use between 1991 to 2004 (Statistics New Zealand, 2004), as a single ethnic group was required for statistical analyses. The MELAA and Other ethnicity groups were combined under the 'Other' category, for the statistical analyses due to small numbers in these ethnic groups. Social deprivation was measured using the New Zealand index of Deprivation (NZDep06). NZDep06 is derived from 2006 census data on nine socio-economic indicators: home ownership; household income; household crowding; access to a telephone; access to a car; single-parent family; means-tested benefits; qualifications, and employment. The index of deprivation score is averaged for a population of a geo-coded address area with scores from 1 (least deprived 10 percent) to 10 (most deprived 10 percent) (Salmond, Crampton, & Atkinson, 2007). Pre-pregnancy BMI was calculated from self-reported pre-pregnancy height and weight.

The National Minimum Dataset is maintained by the Ministry of Health and is a national collection of public and private hospital discharge information, including coded clinical data for inpatients and day patients, and is commonly used to calculate prevalence statistics in the New Zealand health setting (Ministry of Health, 2015). All hospital admissions and births occurring in New Zealand hospitals are captured by the dataset (Ministry of Health, 2015) and it therefore includes women enrolled in the GUiNZ study as well as those in the general population. Data on diagnosis of GDM, DHB, age and ethnicity for all births in 2009 and 2010 were obtained from the Ministry of Health's National Minimum Dataset and were compared with the GUiNZ data. Calculations were made using data from the National Minimum Dataset for women from areas serviced by ADHB, CMDHB and WDHB for 2009 and 2010 combined to match the period and geographical area in which women were recruited to the GUiNZ cohort and used to compare the prevalence of GDM in the GUiNZ cohort obtained in this study with that obtained from the National Minimum Dataset.

Statistical analyses

Statistical analysis was performed using SPSS version 25. Data were checked for accuracy by evaluating descriptive statistics and are reported as frequency (%) for the data available. Pearson Chi squared test and Fishers Exact test were used to analyse frequency data. The proportions of agreement between data sources were calculated according to the methods described by Grant (1991) and are reported as proportion of agreement and 95% confidence interval (CI). The proportions of agreement for both presence and absence of GDM were calculated in three instances: comparing all four data sources of diabetes status (coding data from the Ministry of Health, coding data from DHBs, laboratory data and self-reported data); comparing different sources of medical data (coding data from the Ministry of Health, coding data from DHBs and laboratory data), and comparing pooled medical data to self-reported data. Statistical significance was considered at the $p < 0.05$ level. Descriptive statistics, bar charts and box plots were used to compare characteristics of women in the GUiNZ study to the National Minimum Dataset.

Results

The characteristics of the GUiNZ cohort have been described previously (Morton et al., 2013; Morton et al., 2015). Maternal socio-demographic, health and lifestyle characteristics for women with data on diabetes status during pregnancy (n=6,818) are summarised in Table 4. Self-reported data were available for 6,815 women and

Table 4. Maternal socio-demographic, health and lifestyle characteristics for whom information on diabetes status was available

Maternal characteristic	Growing up in New Zealand (n = 6818)	National Minimum Dataset[1] (n = 42066)
	n (%)	n (%)
Age group (years)		
<20	329 (4.8)	2437 (5.8)
20 - 24	998 (14.6)	7715 (18.3)
25 - 29	1666 (24.4)	10,515 (25.0)
30 - 34	2121 (31.1)	11,520 (27.4)
35 - 39	1419 (20.8)	7750 (18.4)
40 and over	285 (4.2)	2129 (5.1)
Self-prioritised ethnicity		
European	3608 (53.0)	15,054 (35.8)
Māori	950 (14.0)	10,182 (24.2)
Pacific	1001 (14.7)	9355 (22.2)
Asian	1003 (14.7)	6498 (15.4)
Other	241 (3.5)	965 (2.3)
Socioeconomic deprivation decile		
1 to 2 (least deprived)	1099 (16.1)	
3 to 4	1235 (18.1)	
5 to 6	1168 (17.1)	
7 to 8	1426 (20.9)	
9 to 10 (most deprived)	1888 (27.7)	
Highest level of education		
No secondary school	491 (7.2)	
Secondary school / NCEA 1-4	1627 (23.9)	
Diploma/Trade certificate / NCEA 5-6	2082 (30.5)	
Bachelor's degree	1539 (22.6)	
Higher degree	1064 (15.6)	
DHB of domicile		
ADHB	2423 (35.5)	13,566 (32.2)
CMDHB	2526 (37.0)	17,335 (41.2)
WDHB	1869 (27.4)	11,165 (26.5)
Parity		
First child	2852 (41.8)	
Pregnancy planning		
Planned	4091 (60.2)	
Pre-pregnancy BMI (kg/m^2)		
<18.5	256 (4.7)	
18.5 – 24.9	3261 (54.6)	
25 – 29.9	1349 (22.6)	
30 and over	1105 (18.5)	

Data are presented as number of participants and percentages unless otherwise indicated, missing values have not been included in the column %. *n* number, *ADHB* Auckland District Health Board, *CMDHB* Counties Manukau District Health Board, *WDHB* Waikato District Health Board, *NCEA* National Certificate of Educational Achievement, *DHB* District Health Board, *BMI* Body Mass Index. [1]Data from the National Minimum Dataset for women from areas serviced by ADHB, CMDHB and WDHB for 2009 and 2010 combined to match the period and geographical area in which women were recruited to the Growing Up in New Zealand study.

data from the Ministry of Health, DHBs, and laboratories were available for 6,453, 4,385, and 4,741 women respectively through NHI linking. Using combined data from all data sources 67 (1.0%) women were identified as having pre-existing type 1, type 2 or impaired glucose tolerance. A diagnosis of GDM was identified in 422 (6.2%) women in the GUiNZ cohort; however, prevalence varied depending on the data source (Figure 1). Using medical data only i.e. data from the Ministry of Health, DHBs and laboratories, 354 (5.4%) of women were identified as having GDM. Of all 422 women identified as having GDM, GDM was identified by multiple data sources for 260 (61.6%) women. Where other sources of data were either missing or did not report any presence of GDM, laboratory data exclusively identified an additional 87 (20.6%) cases, self-reported data 68 (16.1%), the Ministry of Health 4 (0.9%) and DHBs 3 (0.7%) respectively. Where data on GDM status (GDM and normal glucose tolerance) were available from multiple sources (n=6,483) there were conflicting data for 230 (3.6%) women. The proportion of agreement for presence of GDM was 0.70 (95% CI 0.65, 0.75) and for absence of GDM 0.98 (95% CI 0.97, 0.98) (n=3,840 women with data available from all four data sources). When this analysis was restricted to medical data only (n=5,047 with data from more than one source), 152 (3.0%) women had conflicting data from difference sources. The proportion of agreement between these medical data sources for presence of GDM was 0.71 (95% CI 0.66, 0.76) and for absence of GDM 0.98 (95% CI 0.97, 0.98) (n=3,875 women with data available from all three medical data sources).

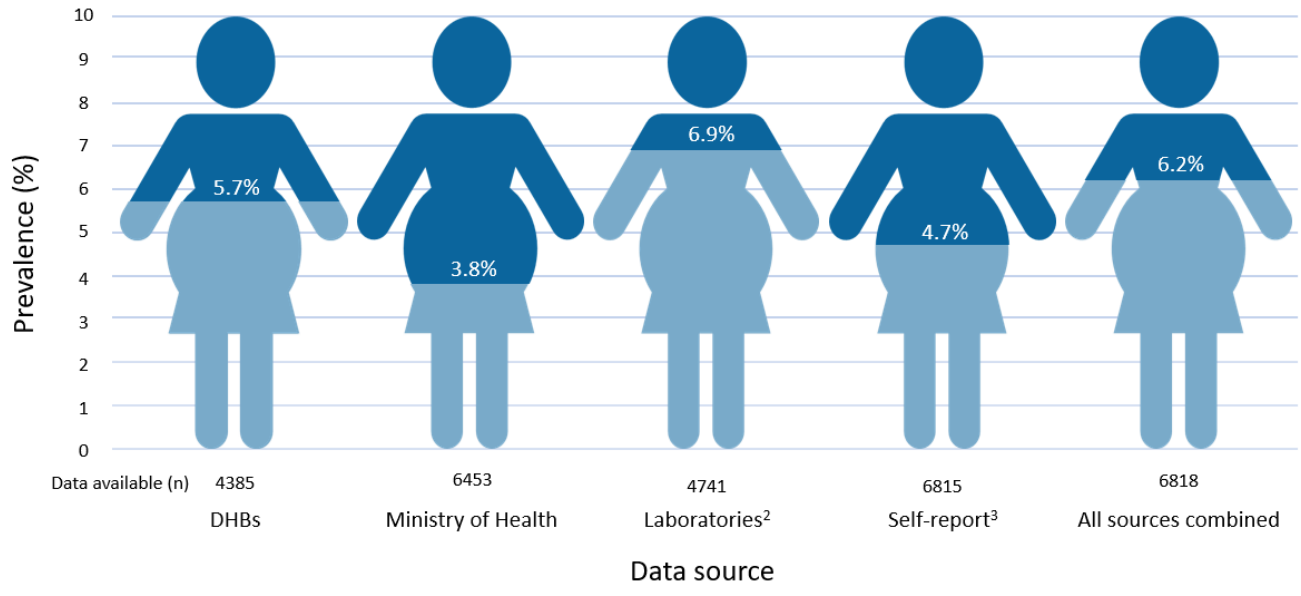

Figure 1. Prevalence of GDM in the Growing Up in New Zealand study according to data source

n number, *DHBs* District Health Boards, *GDM* gestational diabetes mellitus. [2]GDM in laboratory data defined as any positive blood glucose result after 12 weeks' gestation in accordance with the criteria in use for each woman's DHB of domicile during the study period. [3]Self-reported data from antenatal and postpartum data collection points combined using responses "during this pregnancy only" and "for the first time in the last 14 weeks of pregnancy" as a proxy for GDM.

In cases where both self-reported and medical data were available (n=6,441) there was a significant discrepancy in GDM prevalence according to self-report and medical data (Table 5, p <0.0005). Of these women, 176 (2.7%) gave responses to interview administered questionnaires that were inconsistent with medical data. Of the 341 women with medically-documented GDM for whom self-reported data were also available, 115 (33.7%) reported that they did not have any form of diabetes (Table 5). Of the 61 women with GDM according to self-report but no medically-documented GDM, 50 had GCT or OGTT results to suggest that they did not have GDM and none had a diagnosis of GDM coded in the DHB and Ministry of Health data. The proportion of agreement between self-reported data and medical data for a diagnosis of GDM was 0.56 (95% CI 0.51, 0.61) and for an absence of GDM 0.97 (95% CI 0.97, 0.98). Self-reported prevalence of GDM varied between the two data collection points in the interview administered questionnaires. Of 6,802 women who responded to the question in the face-to-face interview administered antenatal questionnaire, 162 (2.4%) women reported having diabetes "only during this current pregnancy" and 266 (4.1%) of 6,802 women replied "yes" when asked if they had diabetes diagnosed for the first time in the last 14 weeks of pregnancy in the 16-month post-partum telephone interview (p <0.0005). When looking at concordance with medical data using self-reported data from each time point separately, 191 (54.3%) of the 352 women with medically-documented GDM reported "never" having diabetes in the antenatal questionnaire and 142 (42.4%) of 335 women with medically documented GDM reported "no" when asked if they had diabetes diagnosed for the first time in the last 14 weeks of pregnancy in the 16-month post-partum telephone interview.

Table 5. GDM status according to self-reported[3] and medical[4] data in Growing Up in New Zealand

Self-reported GDM status[3]	**GDM status according to medical data**[4]		***p* value**
	Normal glucose tolerance	GDM	
No diabetes	6039 (93.7)	115 (1.7)	<0.0005
GDM	61 (0.9)	226 (3.5)	

Data are presented as number of participants and percentages unless otherwise indicated, missing values have not been included in the column %. Women who were identified as having other forms of diabetes either by self-report or medical data (n=113) were excluded from this table. Distributions are compared by Pearson chi-square test. *GDM* gestational diabetes mellitus, *n* number. [3]Self-reported data from antenatal and postpartum data collection points combined using responses "during this pregnancy only" and "for the first time in the last 14 weeks of pregnancy" as a proxy for GDM. [4]Medical data combines data from the District Health Boards, Ministry of Health and laboratories

The National Minimum Dataset has 42,066 live births recorded for ADHB, CMDHB, and WDHB for 2009 and 2010. Of these, 1,552 (3.7%) mothers were coded as having GDM during pregnancy. Maternal characteristics of women in the National Minimum Dataset from ADHB, CMDHB and WDHB for 2009 and 2010 are shown in Table 4 and are comparable to that of women in the GUiNZ study.

Discussion

Main findings

The prevalence of GDM in the GUiNZ study varied significantly between data sources. Using data from all sources, GDM prevalence was 6.2%. When this analysis was restricted to medical data only, GDM prevalence was 5.4%. The prevalence of GDM found in the GUiNZ study cohort was 68% greater than the prevalence from the National Minimum Dataset for the same geographical area during the same time-period. Where data from the GUiNZ cohort were available from multiple sources, data were conflicting for 3.6% of women and levels of agreement for a diagnosis of GDM were poor. We found discrepancies in self-reported data when compared to medical data in which a third of women with a diagnosis of GDM according to medical data reported having no diagnosis of diabetes in self-reported data.

Interpretation

Diagnosis of GDM according to medical records is frequently considered to be a gold-standard data source estimating the prevalence of GDM in a population (Bell et al., 2008; Hosler et al., 2010; Lain et al., 2012); however, review of medical records is labour-intensive, expensive and access to records restrictive. Population health datasets are frequently used to determine disease prevalence and are derived from coding of medical diagnoses present in clinical records (Ministry of Health, 2015), but their accuracy has been questioned (Lain et al., 2012; Winnard, Anderson, MacLennan, Okesene-Gafa, 2013). Self-reported data have been suggested to be an accurate alternative data source for estimating the prevalence of GDM (Gresham et al., 2015; Hinkle et al., 2017; Hosler et al., 2010). However, the substantial differences in GDM prevalence seen according to different data sources in the GUiNZ study and between the GUiNZ cohort and the National Minimum Dataset highlight significant deficiencies in using just one data source to determine GDM prevalence. Where data were available from multiple sources, data were conflicting for 3.6% women and levels of agreement between data sources for presence of GDM were poor.

Other studies evaluating the prevalence of GDM in routinely collected population health datasets have shown similar findings (Bell et al., 2008; Chen et al., 2012; Lain et al., 2012; Zheng et al., 2016). Zheng, Morris and Moses (2016) determined the prevalence of GDM in a private hospital according to the hospital's records and laboratory results and compared this to the New South Wales Perinatal Data collection (Zheng et al., 2016). Much like the findings in our study, there were discrepancies in GDM prevalence according to different data sources and both hospital records and the Perinatal Data collection underestimated the prevalence of GDM. For women who were missing a diagnosis of GDM in the Perinatal Data collection, about half had a diagnosis of GDM documented in the medical records and half were not documented in the women's medical notes (Zheng et al., 2016). Bell et al. (2008) compared information on maternal diabetes status extracted from medical records of a random sample of 1,200 women giving birth in New South Wales, Australia and compared this to two New South Wales Department of Health routinely collected datasets (Bell et al., 2008). Both datasets

underestimated the prevalence of GDM when compared to medical records and given the findings of Zheng, Morris and Moses (2016) where half the cases of GDM were not documented in the medical notes, (Zheng et al., 2016), the discrepancy between the prevalence of GDM recorded in the datasets and the true prevalence of GDM could in fact be even greater.

Other studies have suggested self-reported data provide an accurate estimate of GDM prevalence (Gresham et al., 2015; Hinkle et al., 2017; Hosler et al., 2010). Gresham et al. (2015) investigated the agreement between self-reported perinatal outcomes, collected through repeated surveys, and medical records in the Australian Longitudinal Study on Women's Health. When women were asked specifically about each of their pregnancies, there was an agreement of 97.8%, Kappa 0.66 (p <0.001) between self-reports and medical records for GDM (Gresham et al., 2015). Similarly, in the New York State Pregnancy Risk Assessment Monitoring System (PRAMS) study, Hosler, Nayak and Radigan (2010) examined agreement between participating women's self-report and maternal GDM documented on their children's birth certificates and found percent agreement to be 93.8% with a Kappa statistic of 0.53 (Hosler et al., 2010). Despite these seemingly high levels of agreement, the Kappa statistic used in these studies is testing the correlation between the two reports of GDM but does not test their level of agreement (Grant, 1991). Using the data provided by Gresham et al. (2015) the proportions of agreement between self-reported data and medical records can be calculated to be 0.51 (95% CI 0.47, 0.55) for the presence of GDM and 0.98 (95% CI 0.97, 0.98) for the absence of GDM (Gresham et al., 2015), very similar to our findings. These data also show that 2.2% of women misreported their GDM status according to medical records in the study by Gresham et al. (2015), comparable to the 2.7% found in our study, and 6.2% of women misreported their GDM status in the study by Hosler, Nayak and Radigan (2010). These results question the validity of using self-report as the only data source for estimating GDM prevalence. More importantly, any number of women who misinterpret their diagnosis is likely to have unfavourable consequences. Appropriate treatment of GDM, even in mild cases, has been shown to reduce the risk of adverse pregnancy outcomes (Landon et al., 2009). Our finding that a third of women with a diagnosis of GDM according to medical data did not report having any form of diabetes when asked in interview administered questionnaires raises the question as to whether these women received or adhered to treatment for GDM and warrants further investigation. The greater proportion of women reporting to have GDM and lower incidence of misreporting their diagnosis when compared to medical data at the post-partum time point compared to the antenatal time point could be due to women being diagnosed with GDM after the antenatal questionnaire but could also be due to the difference in interview technique used.

Researchers, healthcare organisations, policy makers and funders rely on prevalence statistics for service planning, policy development and funding allocation. The findings in our study and others' (Bell et al., 2008; Chen et al., 2012; Zheng et al., 2016) indicate that commonly used prevalence statistics are likely underestimating the true prevalence of GDM. By using multiple data sources to determine GDM prevalence,

we were less likely to miss any diagnoses of GDM and therefore give a more accurate estimate of GDM prevalence.

Strengths and limitations

To our knowledge this is the first study evaluating the proportions of agreement between different data sources for the presence and absence of GDM in a population. Although effort was made to have a consistent approach to data collection, not all DHBs provided the same type of information when diabetes coding status was requested using NHI linking. CMDHB provided data on diabetes coding based on ICD-10 codes from their hospital database, while ADHB provided data extracted from their maternity database, and WDHB matched NHIs to their diabetes clinic database and therefore only provided information on women who were registered with the diabetes clinic resulting in a significant number of missing data from ADHB and WDHB. Furthermore, while all three DHBs used a 75 g-OGTT with the same fasting and 2-hour plasma glucose thresholds for diagnosis as their formal diagnostic test, CMDHB additionally used a 50 g screening test for which a plasma glucose concentration at 60 minutes of ≥11.1 mmol/L was considered diagnostic of GDM (Winnard, Anderson, MacLennan, Okesene-Gafa, 2013); thus, the diagnosis of GDM was not made consistently across the cohort. The nature of the different data sources give different denominators when calculating prevalence. For example, the laboratory data includes only those women who were screened for GDM, whilst the Ministry of Health National Minimum Dataset includes all women who delivered at a New Zealand Hospital. Furthermore, although the self-reported data included data collected from more than one time point, the wording used in the interview administered questionnaires did not specifically ask about GDM per se and could be open to interpretation and misclassification in coding. The participants' understanding of these questions could also be influenced by factors such as level of education, the care they received during pregnancy and pregnancy outcome, and may have affected their responses. While these differences may limit the robustness of the data, a major strength of our study is that by pooling results from multiple data sources, we were able to overcome the deficiencies of the different data types to give a more accurate estimate of GDM prevalence. An additional strength is that the prevalence of GDM calculated from NHI linked data from the Ministry of Health of 3.8% was almost identical to the 3.7% prevalence found in the National Minimum Dataset for the same geographical area. This suggests that the cohort of women in the GUiNZ study were broadly representative, at least with respect to risk factors for GDM, to all women giving birth in the catchment area at the time. We acknowledge that the data used to determine prevalence of GDM in this cohort were collected 10 years ago and may not reflect current GDM prevalence. However, to date this is the largest study to estimate GDM prevalence in New Zealand and provides a reference for future research and raises important points to consider when utilising or collecting prevalence statistics.

Conclusions

Our results suggest that the true prevalence of GDM is likely to be different to that commonly reported in the literature, particularly when only one data source is used to determine prevalence. Given that prevalence of GDM varies considerably depending on the data source, this needs to be taken into consideration when evaluating prevalence of GDM and researchers should consider using more than one data source to determine the prevalence of GDM in a population. Inaccuracies in prevalence data are likely to have significant implications for service planning and evaluation, policy development and research. A large proportion of women in New Zealand appear to be unaware of their diagnosis of GDM and thus self-report should not be used to estimate prevalence. Lack of awareness of the diagnosis may impact negatively on a woman's ability to manage GDM and, therefore, potentially on pregnancy outcomes for her and her baby. This discrepancy is concerning and warrants further investigation into communication of the diagnosis to affected women.

Chapter 3

Description of the diets of pregnant women with and without GDM in New Zealand

This chapter is comprised of two manuscripts, both published as a peer review journal articles:

Lawrence RL, Wall CR, Bloomfield FH. Adherence to dietary guidelines among women with and without gestational diabetes in New Zealand. *Nutrients* 2022; 14(10):2145

Lawrence RL, Wall CR, Bloomfield FH. (2020). Dietary patterns and dietary adaptations in women with and without gestational diabetes: Evidence from the Growing Up in New Zealand study. *Nutrients* 12*(*1): 227 - 242

Adherence to dietary guidelines among women with and without gestational diabetes in New Zealand

Introduction

Pregnant women have higher nutritional demands in order to meet their needs and those of their growing fetus (Institute of Medicine, 2005; National Health and Medical Research Council; Ministry of Health, 2006). Diet prior to and during pregnancy can have significant health implications for both mother and baby (Godfrey & Barker, 2000). GDM, carbohydrate intolerance first diagnosed during pregnancy, is one of the most common complications of pregnancy (World Health Organization, 2013). GDM is estimated to effect 6% of pregnancies in New Zealand (Lawrence, Wall, & Bloomfield, 2019). Risk factors for GDM include increased maternal age, family history of diabetes, ethnicity, higher maternal pre-pregnancy BMI and diet (di Cianni et al., 2003; Hedderson et al., 2012; Solomon et al., 1997). Dietary patterns characterised by high intakes of vegetables, fruit. legumes, fish, wholegrains, nuts, seeds and vegetables have been associated with a reduced risk of developing GDM (He et al., 2015; Sartorelli, Zuccolotto, Crivellenti, & Franco, 2019; Schoenaker et al., 2015; Tryggvadottir et al., 2016; Cuilin Zhang, Schulze, et al., 2006). Although dietary patterns give an indication of the diet as a whole, dietary recommendations are commonly based on individual food groups. Food and nutrition guidelines provide practical recommendations for specific populations to assist them achieve estimated nutrient requirements, thereby reducing the risk of developing chronic disease (Nishida, Uauy, Kumanyika, & Shetty, 2004). Greater adherence to food and nutrition guidelines in China has been reported to be associated with a reduced risk of developing GDM (Ding et al., 2021). The GUiNZ study, the largest study of dietary intake of pregnant women in New Zealand, found only 3% of women met the recommended number of daily servings for each of the four food groups and 24% of women did not meet any of the recommendations (Morton et al., 2014). How the diet of women with GDM compares to food and nutrition recommendations and whether greater adherence to recommendations is associated with a reduced risk of developing GDM in New Zealand is unknown. The aim of this study was to describe the proportion of women with GDM meeting the Ministry of Health's Food and Nutrition Guidelines for Pregnant and Breastfeeding Women (FNGPB), determine whether there are differences in adherence between women with and without GDM and whether a diet that adheres to these guidelines is associated with a reduced odds of developing GDM.

Methods

Pregnant women with an estimated due date between April 25, 2009 and March 25, 2010, residing in a demarcated area in the upper-mid North Island of New Zealand and enrolled in GUiNZ (www.growingup.co.nz), an ethnically diverse, longitudinal pre-birth cohort, were eligible to participate. The area specified for recruitment was selected for its ethnic, socioeconomic and environmental diversity to recruit a study

population broadly generalizable to the rest of New Zealand (Morton et al., 2013). Ethical approval was granted on 1 August 2008 by the Ministry of Health Northern Y Regional Ethics Committee (NTY/08/06/055); participating women provided written informed consent. Methodology and reporting is consistent with STROBE guidelines (von Elm et al., 2007).

Data on maternal demographics, health and pregnancy history, smoking status, diet and physical activity were collected in via in-person interviews by trained interviewers. The antenatal interview was completed by 6,822 women and 6,657 consented to the use of their NHI to access their health records. Women interviewed after the child's birth were excluded from this study in order to minimise the effect of recall bias on diet during pregnancy. The mean gestational age at the time of the antenatal data collection interview was 31 (standard deviation (SD) 4) weeks (n = 5,584 for whom data on expected due date were available). Most women (n = 4,365, 78%) completed the interview during the third trimester. Coding criteria used by Statistics New Zealand (Statistics New Zealand, 2005) were used to categorise self-reported ethnicity to one of six categories: European; Māori; Pacific Peoples; Asian; Middle Eastern/Latin American/African (MELAA), and Other. The 'MELAA' and 'Other' ethnic groups were combined into 'Other' due to small numbers. The New Zealand Deprivation Index (NZDep06) (Salmond et al., 2007), was used as a measure of social deprivation and is made up of deciles from 1 (least deprived) to 10 (most deprived). Pre-pregnancy BMI was calculated using self-reported weight and height. The International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003) was used to measure physical activity levels. A semi-quantitative 44-item food frequency questionnaire (FFQ) assessing intake over the past four weeks was administered during the antenatal interview and has been described in detail elsewhere (Morton et al., 2014; Wall et al., 2016). The FFQ was used to ascertain the frequency of consumption of the four food groups as recommended by the Ministry of Health's FNGPB (Ministry of Health, 2006) (summarised in Appendix 1, Table S1). A number of steps were taken to improve the validity of the FFQ and aid comparison with national data. Questions were formatted to be consistent with the 2008/2009 New Zealand Adult National Nutrition Survey (University of Otago & Ministry of Health, 2011). Visual aids were used to assist the reporting of quantities consumed. Description of portion sizes has been demonstrated to increase agreement between FFQ and reference dietary measures (Cade, Thompson, Burley, & Warm, 2002). The FFQ was refined during piloting of its content and delivery with a group of pregnant women enrolled around 6 months ahead of the main cohort (Morton et al., 2010). The proportion of women meeting recommendations for each food group and the number of food groups met were calculated in women with and without GDM.

Information on diabetes in pregnancy was extracted from the Ministry of Health's National Minimum Dataset, regional health boards, and laboratories servicing the recruitment catchment area using participant NHIs. Women were categorised as having GDM if they had a clinical code for GDM or if they had a blood glucose result (between 12 weeks' gestation to the end of pregnancy) meeting the diagnostic criteria for GDM used by

their regional health board at the time. The New Zealand Society for the Study of Diabetes criteria (New Zealand Society for the Study of Diabetes, 1995; Simmons et al., 2006) were used by all three regional health boards. The criteria use a 75 g oral glucose tolerance test to diagnose GDM at ≥5.5 mmol/L for fasting glucose or ≥9.0 mmol/L plasma glucose at 2-h post glucose load. One regional health board also considered a 50 g-GCT result of ≥11.1 mmol/L at 60 minutes post glucose load to be indicative of GDM. Women with pre-existing diabetes or impaired glucose tolerance were excluded from analyses.

Maternal socio-demographic, health and lifestyle characteristics and adherence to food group recommendations are reported as the frequency (%) for categorical variables and mean SD for continuous variables. Cells with n <10 are reported as <10 in accordance with GUiNZ policy. Differences in maternal characteristics and adherence to food group recommendations were tested using Chi squared or Fisher's exact test and unadjusted and adjusted logistic regression. Results are reported as frequency (%), odds ratios (OR) or adjusted odds ratios (aOR) and 95% confidence intervals (CI). Maternal age (<35 and ≥35 years), ethnicity, NZDep06 score (1 to 3, 4 to 7 and 8 to 10), pre-pregnancy BMI (<25, 25 to 29.9 and ≥30 kg/m^2), pre-pregnancy and first trimester physical activity (≥ 150 or 60 minutes per week or moderate or vigorous physical activity respectively), smoking pattern (continued smoking during pregnancy, stopped smoking during pregnancy, non-smoker), alcohol consumption (continued drinking during pregnancy, stopped drinking during pregnancy, non-drinker) and adherence to other food group recommendations were included in adjusted models. The inclusion of variables in adjusted models was based on their association with GDM in univariate or multivariate models or those frequently associated with GDM in the literature. The inclusion and exclusion of participants in this study are shown in Figure 2. Primary analyses were conducted for all women with and without a diagnosis of GDM and stratified analyses were conducted according to the timing of GDM diagnosis in relation to completion of the GUiNZ antenatal data collection interview. Analyses were conducted using SPSS version 21 (IBM Corp., Armonk, NY, USA). A two-sided *p* value of <0.05 was considered statistically significant.

Results

Characteristics of women participating in GUiNZ have been reported previously (Morton et al., 2013). Selection Socio-demographic characteristics of the 5,391 women in primary analyses are shown in Table 6. GDM was identified in 280 (5.2%) of women. For those who had a positive diagnosis according to laboratory data (and therefore an ascertainable date of diagnosis), GDM was diagnosed at a mean of 29.4 (6.0) weeks' gestation. Almost half (44.3%) of women with GDM were diagnosed before the GUiNZ antenatal data collection point and 38.9% of women with GDM were diagnosed after the GUiNZ antenatal data collection point. There were significant differences in a number of maternal characteristics between women with and women without GDM including maternal age, ethnicity, socioeconomic deprivation, pre-pregnancy BMI, gestational weight gain, physical activity, smoking and alcohol consumption (Table 6). Overall, 2.8% of women in the cohort, but 3.2% in women with GDM, adhered to all four food group recommendations (Table 7). Around a quarter of women

did not meet the number of servings recommended in any food group. The number of food groups adhered to was not significantly different between women with and without GDM in primary and stratified analyses (Table 7).

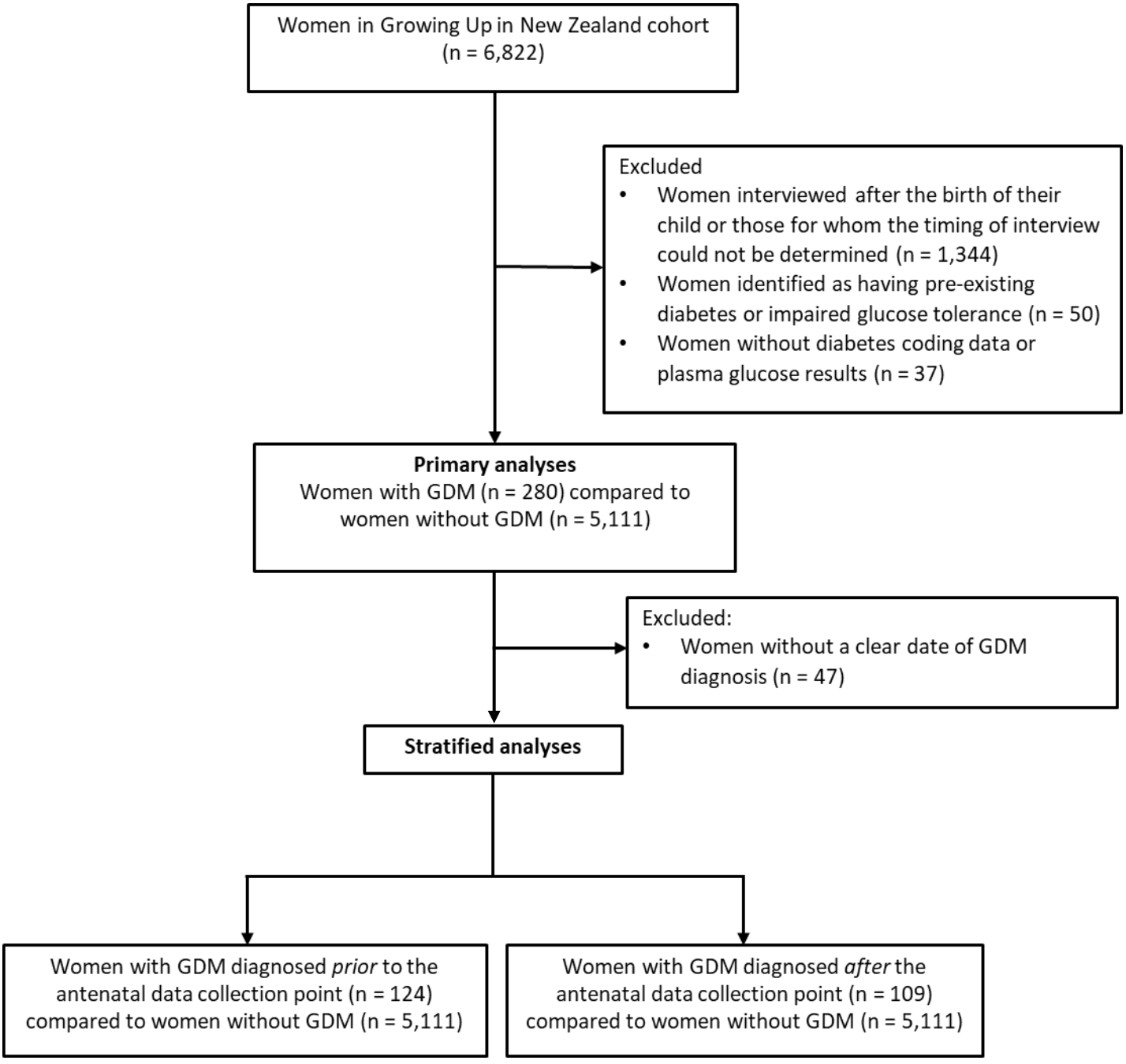

Figure 2. Flowchart showing selection of participants included in primary and stratified analyses of food group recommendation adherence in women with and without GDM from the Growing Up in New Zealand study

Table 6. Characteristics of women in the Growing Up in New Zealand cohort according to GDM diagnosis[1]

	Women without GDM	Women with GDM	*p* value
n (%)	5111 (94.8)	280 (5.2)	
Age group (years)			<0.005
<20	259 (5.1)	<10 (<10)	
20 - 24	747 (14.6)	28 (10.0)	
25 - 29	1267 (24.8)	51 (18.2)	
30 - 34	1662 (31.7)	95 (33.9)	
35 - 39	1039 (20.3)	81 (28.9)	
40 and over	177 (3.5)	20 (7.1)	
Self-prioritised ethnicity			<0.005
European	2915 (57.1)	103 (36.8)	
Māori	690 (13.5)	22 (7.9)	
Pacific	631 (12.4)	55 (19.6)	
Asian	681 (13.3)	84 (30.0)	
Other	186 (3.6)	16 (5.7)	
Parity			
First child	2168 (42.4)	123 (43.9)	0.619
Socioeconomic deprivation			0.021
1 to 2 (least deprived)	865 (16.9)	30 (10.7)	
3 to 4	978 (19.1)	45 (16.1)	
5 to 6	909 (17.8)	61 (21.8)	
7 to 8	1052 (20.6)	63 (22.5)	
9 to 10 (most deprived)	1305 (25.5)	81 (28.9)	
Pre-pregnancy BMI (Kg/m^2)			<0.005
<18.5	192 (4.2)	<10 (<10)	
18.5 to 24.9	2559 (56.2)	103 (41.4)	
25 to 29.9	1034 (22.7)	60 (24.1)	
≥30	772 (16.9)	79 (31.7)	
Gestational weight gain			0.005
Gained ≥5kg	4460 (88.9)	229 (83.0)	
Gained <5kg	377 (7.5)	32 (11.6)	
No change	43 (0.9)	<10 (<10)	
Lost <5kg	74 (1.5)	10 (3.6)	
Lost ≥5kg	62 (1.2)	<10 (<10)	
Physical activity[2]			
Physically active pre-pregnancy	2583 (50.5)	119 (42.5)	0.009
Physically active during first trimester	1464 (28.6)	62 (22.1)	0.019
Physically active during second & third trimester	1152 (22.5)	59 (21.1)	0.567
Smoking patterns			0.012
Continued smoking	509 (10.0)	13 (4.6)	
Stopped smoking	494 (9.7)	31 (11.1)	
Non-smoker	4094 (80.3)	236 (84.3)	
Alcohol consumption			<0.005
Any drinking during pregnancy	1539 (30.1)	42 (15.0)	
Stopped drinking	2279 (44.6)	100 (35.7)	
Non-drinker	1288 (25.2)	138 (49.3)	

n number, *BMI* Body Mass Index, *GDM* gestational diabetes mellitus. [1]Includes only women interviewed before the birth of their child and excludes women with other forms of diabetes or for whom diabetes status could not be determined; data are presented as number of participants (%), missing values have not been included in the column %; [2]engaged in moderate or vigorous physical activity for at least 150 or 60 minutes per week respectively.

Table 7. Adherence to Ministry of Health food group recommendations

Adherence to food group recommendations	Primary analyses		Stratified analyses	
	Women without GDM	Women with GDM	GDM diagnosed prior to FFQ	GDM diagnosed after FFQ
	n = 5109	n = 280	n = 124	n = 109
Four food groups	144 (2.8)	<10 (<10)	<10 (<10)	<10 (<10)
Three food groups	517 (10.1)	31 (11.1)	<10 (<10)	13 (11.9)
Two food groups	1295 (25.3)	68 (24.3)	32 (25.8)	27 (24.8)
One food group	1954 (38.2)	97 (34.6)	49 (39.5)	33 (30.3)
No food groups	1199 (23.5)	75 (26.8)	32 (25.8)	31 (28.4)
Fruit	4245 (83.1)	228 (81.4)	91 (73.4)[a]	95 (87.2)
Vegetables	1382 (27.0)	87 (31.1)	37 (29.8)	35 (32.1)
Breads and cereals	1350 (26.4)	66 (23.6)	25 (20.2)	25 (22.9)
Milk and milk products	2986 (58.4)	140 (50.0)[a]	57 (46.0)[a]	60 (55.0)
Lean meat, poultry, seafood, eggs, nuts and seeds and legumes	1073 (21.0)	81 (28.9)[b]	36 (29.0)[a]	30 (27.5)

Data presented as number of participants (%). [a]$p < 0.05$; [b]$p < 0.005$ from Chi squared analyses

The greatest adherence in both women with and without GDM was seen in the proportion of women meeting recommendation for fruit intake (Table 7). Significantly fewer women with GDM met recommendations for milk and milk products and significantly more women with GDM met recommendations for lean meat, poultry, seafood, eggs, nuts and seeds and legumes. When analyses were stratified according to timing of diagnosis, significantly fewer women with GDM diagnosed prior to the antenatal data collection point (and administration of the FFQ) met the recommended number of servings for fruit, milk and milk products compared to women without GDM and more met the recommendations for lean meat, poultry, seafood, eggs, nuts and seeds and legumes (Table 7). There were no significant differences in the number of women meeting the recommendations for any food group when analyses were restricted to only women with GDM diagnosed after the antenatal data collection point and women without GDM.

Meeting the recommended number of servings for milk and milk products was associated with a significantly reduced odds of developing GDM in the unadjusted model (Table 8). In contrast, meeting the recommended number of servings for lean meat, poultry, seafood, eggs, nuts and seeds and legumes was associated with a significantly increased odds of developing GDM. In unadjusted stratified analyses of women with a diagnosis before the antenatal data collection point, meeting the recommendations for the number of servings of fruit also was associated with a reduced risk of developing GDM, but no significant associations were present in unadjusted analyses including only women with a diagnosis of GDM made after the data collection point (and therefore unlikely tpo be aware of their forthcoming diagnosis of GDM at the time of data collection) (data not shown). After adjustment, these associations diminished and were no longer significant in both primary and stratified analyses. Meeting any number of food group recommendations did not significantly influence odds of developing GDM in unadjusted or adjusted analyses in both primary and stratified analyses (Table 8).

Table 8. Unadjusted and adjusted odds of having GDM according to adherence Ministry of Health food group recommendations

	Primary analyses		Stratified analyses	
Adherence to food group recommendations	**OR (CI)** n = 5391	**aOR (CI)** n = 4784	**GDM diagnosed prior to FFQ and women without GDM aOR (CI)** n = 4647	**GDM diagnosed after FFQ and women without GDM aOR (CI)** n = 4629
Four vs at least three food groups	1.15 (0.58, 2.27)	0.88 (0.41, 1.89)	0.69 (0.44, 1.10)	1.46 (0.78, 2.73)
At least three vs at least two food groups	1.12 (0.80, 1.58)	1.12 (0.77, 1.62)	1.24 (0.81, 1.90)	1.32 (0.84, 2.06)
At least two vs at least one food groups	1.01 (0.79, 1.30)	1.07 (0.81, 1.41)	0.60 (0.35, 1.00)	0.80 (0.48, 1.34)
At least one vs no food groups	0.84 (0.64, 1.10)	0.95 (0.70, 1.28)	0.89 (0.60, 1.33)	0.95 (0.62, 1.46)
Four vs no food groups	1.00 (0.49, 2.04)	0.77 (0.34, 1.77)	1.30 (0.83, 2.04)	1.06 (0.65, 1.75)
Fruit	0.89 (0.66, 1.22)	1.00 (0.70, 1.43)	0.69 (0.44, 1.10)	1.46 (0.78, 2.73)
Vegetables	1.22 (0.94, 1.58)	1.24 (0.93, 1.66)	1.24 (0.81, 1.90)	1.32 (0.84, 2.06)
Breads and cereals	0.86 (0.65, 1.14)	0.82 (0.59, 1.14)	0.60 (0.35, 1.00)	0.80 (0.48, 1.34)
Milk and milk products	0.71 (0.56, 0.91)*	0.93 (0.71, 1.22)	0.89 (0.60, 1.33)	0.95 (0.62, 1.46)
Lean meat, poultry, seafood, eggs, nuts and seeds and legumes	1.53 (1.17, 2.00)**	1.21 (0.88, 1.65)	1.30 (0.83, 2.04)	1.06 (0.65, 1.75)

Adjusted odds ratio (aOR) (95% CI) from adjusted logistic regression (maternal age group, ethnicity, socioeconomic deprivation, pre-pregnancy BMI, pre-pregnancy and 1st trimester physical activity, smoking, alcohol consumption and adherence to food group servings). *$P < 0.05$; **$P < 0.005$

Discussion

Overall adherence to the Ministry of Health's FNGPB (Ministry of Health, 2006) was poor in women with and without GDM. Less than 4% of women met recommendations for all food groups. Significantly fewer women with GDM reported consuming the recommended number of servings for milk and milk products and more consumed the recommended of servings for lean meat, poultry, seafood, eggs, nuts and seeds and legumes compared to women without GDM; however, in stratified analysis this was only the case in women whose diagnosis was made prior to data collection point (and therefore presumable aware of their diagnosis at the time). Women whose diagnosis of GDM was made after the antenatal data collection point and who, therefore, were presumably unaware of their impending diagnosis met recommendations for food groups in similar proportions to women without GDM. This suggests women with a diagnosis of GDM made prior to the GUiNZ antenatal data collection had made adaptations to their diet prior to completing the FFQ, perhaps as a result of their diagnosis or on receiving dietary advice for the management of GDM. In New Zealand, women with GDM are referred a specialist Diabetes in Pregnancy Team which typically includes an obstetrician, diabetes physician, diabetes midwife and dietitian (Ministry of Health, 2014). Many have already received nutrition advice prior to

dietetic input at the Diabetes in Pregnancy Clinic (Lawrence, Wall, Bloomfield, & Crowther, 2016). There were no significant associations between meeting any food group or any number of food groups in adjusted analyses in both primary or stratified analyses. While many studies have found associations between diet and GDM (Hassani Zadeh et al., 2020), our data showed no significant relationship between meeting recommendations for the number of servings for different food groups with the risk of GDM.

In a study using the Australian Recommended Food Score (ARFS), a measure of diet quality according to Australian dietary guidelines, Gresham et al. (2016) found women with higher ARFS had a lower risk of developing gestational hypertension but not of developing GDM. Women with GDM did, however, have a higher mean score for the vegetable component of the ARFS compared to women without GDM (Gresham, Collins, Mishra, Byles, & Hure, 2016). Given the FFQ used by Gresham et al. could have been completed by women up until the time of the birth of their baby, this finding may be due to a treatment affect as seen in our results. Gicevic et al. (2018) explored whether different measures of diet diversity and diet quality could predict risk of developing GDM in a group of 21,312 women participating in the Nurses' Health Study II (Gicevic et al., 2018). There were no associations between scores on two diet diversity measures and the risk of GDM; however, higher scores on both the Alternate Health Eating Index-2010 (aHEI-2010) and the Prime Diet Quality Score (PDQS) were associated with a significantly reduced risk of GDM. Similarly, a study of 1,489 women participating in the Tongji Maternal and Child Health Cohort study reported a higher score on the newly developed Chinese Dietary Guidelines Compliance Index for Pregnant Women was associated with a reduced risk of GDM (Ding et al., 2021). These scores of diet quality provide a more comprehensive assessment of diet quality as scoring is based on both positive and negative dietary components with scores added for 'healthy' foods and subtracted for 'unhealthy' foods or nutrients. The scores of diet diversity are a cruder measure of dietary intake as only positive scores are awarded based on consumption of the different food groups (Gicevic et al., 2018) and scores do not take into account intake of 'unhealthy' food items, similar to measures of adherence to food group recommendations used in our study. In contrast to the findings reported here, our analyses of dietary patterns in the same cohort of women in GUiNZ found significant differences in mean dietary pattern scores between women with and without GDM (Lawrence, Wall, & Bloomfield, 2020). Given dietary pattern scores consider the eating pattern as a whole, whilst measures of adherence to food and nutrition recommendations consider only those foods recommended by the guidelines, it may be that such measures of diet quality are not sensitive enough to predict risk of GDM.

The findings reported here highlight poor adherence to food and nutrition recommendations by pregnant women in New Zealand, despite the majority of women reporting receiving dietary information leading to dietary changes during pregnancy (Lawrence et al., 2020). Our findings are consistent with a recent study exploring adherence to food recommendations in 313 women with GDM in New Zealand which found no woman to meet all food recommendations (Mustafa, Harding, Wall, & Crowther, 2021). Although pregnant

women are often thought to be amenable to improving health behaviours during pregnancy (Hillier & Olander, 2017; Olander, Atkinson, Edmunds, & French, 2012), numerous studies have shown that the quality of women's diets during pregnancy is poor (Malek, Umberger, Makrides, & Zhou, 2016; Wen, Flood, Simpson, Rissel, & Baur, 2010). A survey of 400 pregnant women in Australia found 65% of women were not familiar with the Australian Guide to Healthy Eating for pregnancy and reported limited differences in women's nutrition knowledge according whether women had accessed a dietitian or nutritionist (Bookari, Yeatman, & Williamson, 2016). Women who had seen a dietitian or nutritionist for GDM scored significantly lower than other groups in their knowledge of the recommended intakes for the five food groups (Bookari et al., 2016). There are no reports of women's knowledge of dietary guidelines in New Zealand; however, there are reports indicating that women in New Zealand do make dietary changes during pregnancy (Brown, von Hurst, Rapson, & Conlon, 2020; Lawrence et al., 2020; Paterson, Hay-Smith, & Treharne, 2016). A survey of 458 women in New Zealand found that, although some women reported using the Ministry of Health's FNGPB, midwives were the most influential source of dietary information during pregnancy, with over 75% of women reporting receiving dietary advice from their lead maternity carer, consistent with findings previously reported in the same cohort of women included this study (Lawrence et al., 2020). Clearly, these healthcare professionals play an important role in informing women about the dietary guidelines; however, nutrition is only one of the many topics midwives are expected to cover when caring for pregnant women. Internationally, surveys of midwives have reported a lack of knowledge and confidence in providing nutrition education (Arrish, Yeatman, & Williamson, 2014, 2016). In New Zealand, midwives report limited formal nutrition education (Elias & Green, 2007) and desire more support in delivery of nutrition advice (Pan et al., 2014). Although New Zealand midwives use the New Zealand Ministry of Health's FNGPB to inform their nutrition knowledge (Elias & Green, 2007) current strategies for nutrition education in pregnant women clearly are not sufficiently effective in influencing behaviour change. Whilst food and nutrition guidelines are valuable in providing evidence-based advice, further work is needed in their implementation and evaluation in promoting behaviour change. Dietitians are trained to evaluate scientific evidence about food and nutrition and translate it into practical strategies to help people improve their health and lifestyle through nutrition (Dietitians Board, 2021). Early management of GDM and regular contact with a dietitian has been associated with measurable changes in diet (Morisset et al., 2014). In New Zealand, not all women with GDM are seen by dietitians, and many are seen only once (Lawrence et al., 2016). Whether greater input from a dietitian leads to improved diet and pregnancy outcomes in women with GDM warrants further investigation.

Strengths and limitations

This is the first study describing differences in adherence to dietary guidelines between women with and without GDM in New Zealand. Strengths include the large, ethnically diverse sample, the ascertainment of GDM diagnosis through a number of sources and stratification of analyses according to timing of GDM diagnosis in relation to completion of the FFQ. A limitation is that the FFQ administered examined dietary intake over

just four weeks and has not been validated in this population. The broad groupings of foods included in each food group recommendation may limit the usefulness of using adherence to these guidelines to determine differences in risk of GDM given that different foods included in the same food group recommendation may have opposing associations with GDM risk. For example, nuts and seeds and red meat are included in the same recommendation but have been found to be associated with a reduced and increased risk of GDM respectively (Bao, Bowers, Tobias, Hu, & Zhang, 2013). A further limitation is that the data collected for the analyses conducted in this study are over 10 years old. Analyses were therefore based on the older Ministry of Health's FNGPB (Ministry of Health, 2006), rather than the Eating and Activity Guidelines for New Zealand adults updated in 2020 to include statements relating to pregnant and breastfeeding woman (Ministry of Health, 2020b). The Eating and Activity guidelines have different portion size recommendations and recommend a different number of servings for each of the four food groups compared to previous guidelines. Administration of FFQs on a large-scale is both timely and costly. At the time of analyses, the GUiNZ study provided the most recent large-scale dataset with both FFQ and GDM diagnosis data available; whether there have been changes to women's diets and whether there are differences in adherence to these newly published recommendations warrants further investigation.

Conclusion

In this large, prospective, cohort of pregnant women, adherence to the Ministry of Health's FNGPB was not significantly associated with the odds of having GDM, most likely due to a lack of sensitivity in using the guidelines as a tool to tease out dietary factors associated with GDM. There were no differences between women with and without GDM in the proportions who met food group recommendations once potential confounding factors were adjusted for. Nevertheless, these findings highlight that pregnant women, even when they have GDM - a condition modifiable by diet - have poor adherence to dietary recommendations. This could lead to poor health for both mother and baby. Differences in adherence to food groups in women with GDM according to timing of diagnosis suggest women make changes to their diet either as a result of their diagnosis or on receiving advice for their diagnosis. Therefore, more support than what is currently provided, for example, more support from a dietitian, may lead to greater adherence to food and nutrition recommendations. Further research on how this can best be achieved and whether the update to the dietary guidelines for pregnant women yields different results is needed.

Dietary patterns and dietary adaptations in women with and without gestational diabetes: Evidence from the Growing Up in New Zealand Study

Introduction

Pregnancy is a time when women frequently pay extra attention to their diet in order to promote the health and wellbeing of themselves and their baby (Lewallen, 2004; Szwajcer, Hiddink, Maas, Koelen, & van Woerkum, 2012; Szwajcer, Hiddink, Koelen, & Van Woerkum, 2005; Szwajcer, Hiddink, Maas, Koelen, & van Woerkum, 2009). Women receive information from a range of sources (Lewallen, 2004; Szwajcer et al., 2009) and make a number of dietary adaptations during pregnancy (Hillier & Olander, 2017). Diet is thought to play a critical role in the development of GDM, a form of carbohydrate intolerance first diagnosed in pregnancy (World Health Organization, 2013), and a number of dietary components have been associated with an increased or decreased risk of GDM (Bowers et al., 2012, 2011; Chen, Hu, Yeung, Willett, & Zhang, 2009; Zhang et al., 2004; Zhang, Liu, Solomon, & Hu, 2006). GDM poses significant health risks to both mother and infant (González-Quintero et al., 2007; The HAPO Study Cooperative Research Group, 2008; Vambergue et al., 2002) extending beyond the pregnancy and neonatal period (Boney, Verma, Tucker, & Vohr, 2005; Cho, Silverman, Rizzo, & Metzger, 2000). Rates of GDM-affected pregnancies are increasing, thought to be at least in part due to concomitant increasing prevalence of overweight and obesity (Hunt & Schuller, 2007; Ignell, Claesson, Anderberg, & Berntorp, 2014; Lavery et al., 2016). Globally, reported prevalence of GDM ranges between 1 and 45% of pregnancies (Agarwal et al., 2015; Buckley et al., 2012; Zhu & Zhang, 2016). In New Zealand, GDM has been estimated to affect around 6% of pregnancies (Lawrence, Wall, & Bloomfield, 2019).

Dietary pattern analysis has become a popular tool for exploring dietary associations with GDM, as it is thought to better reflect real eating behaviours by considering the eating pattern as whole (Hu, 2002). A number of studies have found dietary patterns characterised by high intakes of red and processed meats, fried foods and added sugars, to be associated with an increased risk of GDM, while dietary patterns characterised by high consumption of fruit, vegetables, wholegrains and nuts or 'Mediterranean' style dietary patterns to be associated with a lower risk of developing GDM (Donazar-Ezcurra et al., 2017; Gicevic et al., 2018; He et al., 2015; Izadi et al., 2016; Schoenaker et al., 2015; Sedaghat et al., 2017; Shin et al., 2015; Tobias et al., 2012; Tryggvadottir et al., 2016; Zareei et al., 2018; Zhang, Schulze, et al., 2006). Nonetheless, research of dietary patterns and risk of GDM has primarily been conducted in largely Caucasian populations (Bao, Bowers, et al., 2014; Donazar-Ezcurra et al., 2017; Tobias et al., 2012; Tryggvadottir et al., 2016; Zhang, Liu, et al., 2006), with many using data from the same cohort of women from the Nurses' Health Study II (Bao, Bowers, et al., 2014; Tobias et al., 2012; Zhang, Schulze, et al., 2006). Ethnicity is widely accepted risk factor for GDM (Hedderson, Darbinian, et al., 2010), with women of non-European descent disproportionately affected (National Women's Health, 2019). Different ethnic populations tend to have different diets (Blumfield, Hure, Macdonald-Wicks,

Smith, & Collins, 2012), which may further influence the risk of developing GDM. Dietary patterns and adherence to nutrition recommendations have been reported to differ amongst pregnant women of different ethnicities within New Zealand (Morton et al., 2014; Wall et al., 2016); however, associations between diet and the development of GDM have not been explored in the New Zealand population. Whether women who develop GDM make similar dietary adaptations during pregnancy to those who do not develop GDM is also unknown. The aim of this study was therefore to explore differences in dietary patterns and dietary adaptations among women with and without a diagnosis of GDM during pregnancy in New Zealand.

Materials and Methods

Study population

Data used for the analyses in this study were derived from 6,822 women enrolled in the GUiNZ study (www.growingup.co.nz), a pre-birth, longitudinal cohort study exploring multidisciplinary determinants of health and development for children born in New Zealand (Morton et al., 2013). Pregnant women with an estimated due date between 25th April 2009 and 25th March 2010 residing in an area defined by the geographical boundaries of three regional health boards in the upper-mid North Island of New Zealand were eligible to participate in the study. The geographical area of recruitment was chosen for its ethnic, socio-economic and urban and rural residency diversity with the aim of having a study cohort that was broadly generalizable to the rest of New Zealand (Morton et al., 2013). Ethical approval was provided by the Ministry of Health Northern Y Regional Ethics Committee (reference NTY/08/06/055) and written informed consent was obtained from all participating women.

Data collection

Data collection during the antenatal period comprised of a face-to-face interview collecting information on maternal demographics, health and pregnancy history, smoking status, dietary intake and physical activity. A total of 6,822 women consented and completed the antenatal interview (most often during the third trimester of pregnancy) and 6,657 consented to access to their routine health records through use of their unique National Health Identifier (NHI).

Measurements

Diabetes status during pregnancy

The methods used to identify women with GDM in the cohort have been described previously (Lawrence et al., 2019). Briefly, participant NHIs were used to obtain data on diabetes status during pregnancy from the Ministry of Health's National Minimum Dataset, the three regional health boards, and laboratories servicing the recruitment catchment area. Coded clinical data were collected from the Ministry of Health and the three regional health boards. Laboratories provided fasting plasma glucose concentration, glucose challenge test results and glucose tolerance test results. Women were classified as having GDM if they had a clinical code for GDM or if they

had a blood glucose result (between 12 weeks' gestation to the end of pregnancy) meeting the diagnostic criteria for GDM in use by their regional health board at the time. All three regional health boards used the New Zealand Society for the Study of Diabetes criteria (New Zealand Society for the Study of Diabetes, 1995; Simmons et al., 2006) to diagnose GDM: fasting plasma glucose of ≥5.5 mmol/L or a 2-hour plasma glucose ≥ 9.0 mmol/L post 75 g-OGTT (National Women's Health, 2010, 2011; Winnard, Anderson, MacLennan, Okesene-Gafa, 2013, Jade Tamatea, Endocrinologist, WDHB, emailed personal communication, April 27, 2017). One regional health board also considered a 60-minute plasma glucose result on the 50 g-GCT of ≥11.1 mmol/L to be indicative of GDM (Winnard, Anderson, MacLennan, Okesene-Gafa, 2013). Women identified as having pre-existing diabetes or impaired glucose tolerance were excluded from analyses.

Dietary patterns and dietary habits

A semi-quantitative 44-item food frequency questionnaire administered as part of the antenatal interview was used to collect information on dietary intake and has been described in detail elsewhere (Morton et al., 2014; Wall et al., 2016). The purpose of the antenatal food frequency questionnaire was to describe the frequency of consumption over the previous four weeks of the four core food groups as recommended by the New Zealand Ministry of Health's guidelines for pregnant women (Ministry of Health, 2006): fruits and vegetables; breads and cereals; milk, milk products, lean meat, meat alternatives and eggs, and foods likely to be high in fats, sugars and/or salt. Four dietary patterns have previously been identified in the cohort using principle component analysis as described by Wall et al. (2016). The dietary patterns identified were labelled as 'Junk', 'Health conscious', 'Traditional/White bread' and 'Fusion/Protein'. Food items with factor loadings of 0.3 or greater in the principle component analysis were considered to be strongly associated with the identified pattern. The 'Junk' dietary pattern had high loadings of confectionary, snacks, takeaways, hot chips, processed meats, soft and energy drinks, battered fried fish or seafood, ice-cream and cakes or biscuits. The 'Health conscious' dietary pattern had high loadings of vegetables, cheese, brown wholemeal bread, non-citrus fruits, yoghurt, dried fruits, high fibre cereal, and Vegemite™ or Marmite™. The 'Traditional/White bread' had high factor loadings for whole or standard milk, white bread, margarine, jam honey marmalade, peanut butter, Nutella™ and low fibre and/or high sugar cereals. The 'Fusion/Protein' had high factor loadings for noodles, rice, pasta, seafood, chicken, green leafy vegetables, eggs and red meat (Wall et al., 2016). Summary scores for each dietary pattern were available for 5,664 women who had antenatal dietary data. A higher score indicates a stronger adherence to that dietary pattern.

The antenatal questionnaire also included open questions regarding foods or drinks deliberately avoided or added to the diet due to pregnancy (Morton et al., 2010) and were categorised as 'breads and cereals', 'lean meat, chicken, seafood, eggs, cooked dried beans, peas', 'milk and milk products', 'fruit and vegetables', 'supplement', 'chocolate', 'foods high in fat or sugar', 'alcohol', 'soft drinks' and 'other'. Women were asked whether they had received any information or been told anything that led them to make dietary changes while pregnant. If they answered 'yes' to this question they were asked to select from a list of information sources including

'family/whānau', 'friends', 'GP (Family doctor)', 'midwife', 'obstetrician', 'dietitian/nutritionist', alternative health practitioner', 'antenatal class', 'the internet', 'radio', 'TV', 'books, magazines, newspaper', or 'other'.

Covariates

Questions relating to maternal socio-demographic, health and lifestyle characteristics were also included in the antenatal interview. Self-reported ethnicity was allocated to one of six Level 1 categories (i) European; (ii) Māori; (iii) Pacific Peoples; (iv) Asian; (v) Middle Eastern / Latin American / African (MELAA), and (vi) Other ethnicity according to the coding criteria used by Statistics New Zealand (Statistics New Zealand, 2005). If women identified with multiple ethnicities and did not self-prioritise a primary ethnicity, the prioritisation methodology employed by Statistics New Zealand between 1991 to 2004 (Statistics New Zealand, 2004) was used, as mutually exclusive ethnic groups were required for statistical analyses. The 'MELAA' and 'Other' ethnic groups were combined into the 'Other' ethnic group due to small numbers in these groups. The New Zealand Deprivation Index (NZDep06) (Salmond et al., 2007) was used as a measure of social deprivation. The index is divided into deciles from 1 (least deprived) to 10 (most deprived). Pre-pregnancy weight and height were self-reported and used to calculate pre-pregnancy BMI. Weight gain during pregnancy up to the point of the antenatal interview was assessed in a question asking about weight change during pregnancy in 5 Kg increments. Women were also asked whether they were actively dieting or trying to lose weight during the 6 months prior to pregnancy and whether or not they lost any weight during that time. Physical activity was assessed using questions from the International Physical Activity Questionnaire (IPAQ). Participants were asked about intensity (moderate or vigorous), duration (<30, 30 to 60, or >60 minutes) and frequency (days per week) of activity (Craig et al., 2003). To be classified as participating in moderate or vigorous activity women had to have engaged in moderate activity for at least 30 minutes for at least five days per week or vigorous activity for at least 30 minutes on at least two days per week. Women were asked if they received any treatment to assist them in becoming pregnant and if women answered 'yes', this question was followed by a multiple response question relating the type of treatment given which included 'fertility awareness and weight loss'.

Statistical analyses

Maternal socio-demographic, health and lifestyle characteristics and dietary patterns are reported as frequency (%) for categorical variables and mean ± standard deviation (SD) for continuous variables. Cells with n <10 are reported as <10 in accordance with GUiNZ policy. Differences in maternal characteristics and dietary patterns were tested using Chi squared or Fisher's exact test and unadjusted and adjusted logistic regression for categorical variables and independent samples t-test for continuous variables. Results are reported as mean (SD), frequency (%) or odds ratios (OR) or adjusted odds ratios (aOR) and 95% confidence intervals (CI). Maternal age (<35 and ≥35 years), ethnicity (European, Māori, Pacific, Asian, Other) NZDep06 score (1 - 3, 4 - 7 and 8 - 10), pre-pregnancy BMI (<25, 25 - 29.9 and ≥30 Kg/m^2), pre-pregnancy and first trimester physical activity (at least 150 minutes per week of moderate to vigorous physical activity), smoking pattern (continued smoking during pregnancy, stopped

smoking during pregnancy, non-smoker), alcohol consumption (continued drinking during pregnancy, stopped drinking during pregnancy, non-drinker) and dietary pattern score were included in adjusted models. These variables were selected as they either were associated with GDM in univariate or multivariate analyses or are commonly considered to be associated with the risk of developing GDM in the literature. Analyses were conducted using SPSS version 21. A two-sided *p* value of <0.05 was considered statistically significant.

Results

The characteristics of women participating in the GUiNZ study have been described previously (Morton et al., 2013). The selection of participants included in this study is shown in Figure 3. Socio-demographic, health and lifestyle characteristics of the 5,384 women included in the analyses of this study are shown in Table 9. GDM was identified in 280 (5.2%) of women. There were significant differences in maternal age, ethnicity, socioeconomic deprivation, pre-pregnancy BMI, physical activity pre-pregnancy and during the first trimester, pre-pregnancy dieting status, smoking patterns and alcohol consumption between women with and without GDM (Table 9).

Dietary pattern scores differed between women diagnosed with GDM and those without GDM (Table 10). Women with GDM had significantly lower mean scores for 'Junk' and 'Traditional/White bread' dietary patterns and a significantly higher mean score for the 'Fusion Protein' dietary pattern. Logistic regression analysis showed higher scores on the 'Junk' OR (per 1 SD change) 0.61 (95% CI; 0.51, 0.74) $p \leq 0.0005$ and the 'Traditional/White bread' dietary patterns OR 0.89 (0.71, 0.93) $p = 0.002$ were associated with a decreased odds of having GDM and higher scores on the 'Fusion/Protein' dietary pattern OR 1.25 (1.13, 1.38) $p \leq 0.0005$ were associated with an increased odds of having GDM. Although not statistically significant, there was a strong trend of a higher score on the 'Health conscious' dietary pattern to be associated with a reduced likelihood of having GDM OR 0.89 (0.78, 1.00) $p = 0.055$ in unadjusted analyses. After adjusting for maternal age, ethnicity, socioeconomic deprivation, pre-pregnancy BMI, pre-pregnancy and first trimester physical activity, smoking patterns, alcohol consumption and dietary pattern score on alternative dietary patterns, higher scores on 'Junk' aOR 0.64 (0.52, 0.80) $p = 0.001$ and 'Traditional/White bread' aOR 0.66 (0.55, 0.78) $p \leq 0.0005$ dietary patterns remained significantly associated with a reduced likelihood of having GDM, while the relationship between scores on the 'Fusion/Protein' and 'Health conscious' dietary patterns were attenuated and not significantly associated with GDM status aOR 1.04 (0.90, 1.2) $p = 0.269$ and aOR 1.11 (0.96, 1.29) $p = 0.378$ respectively.

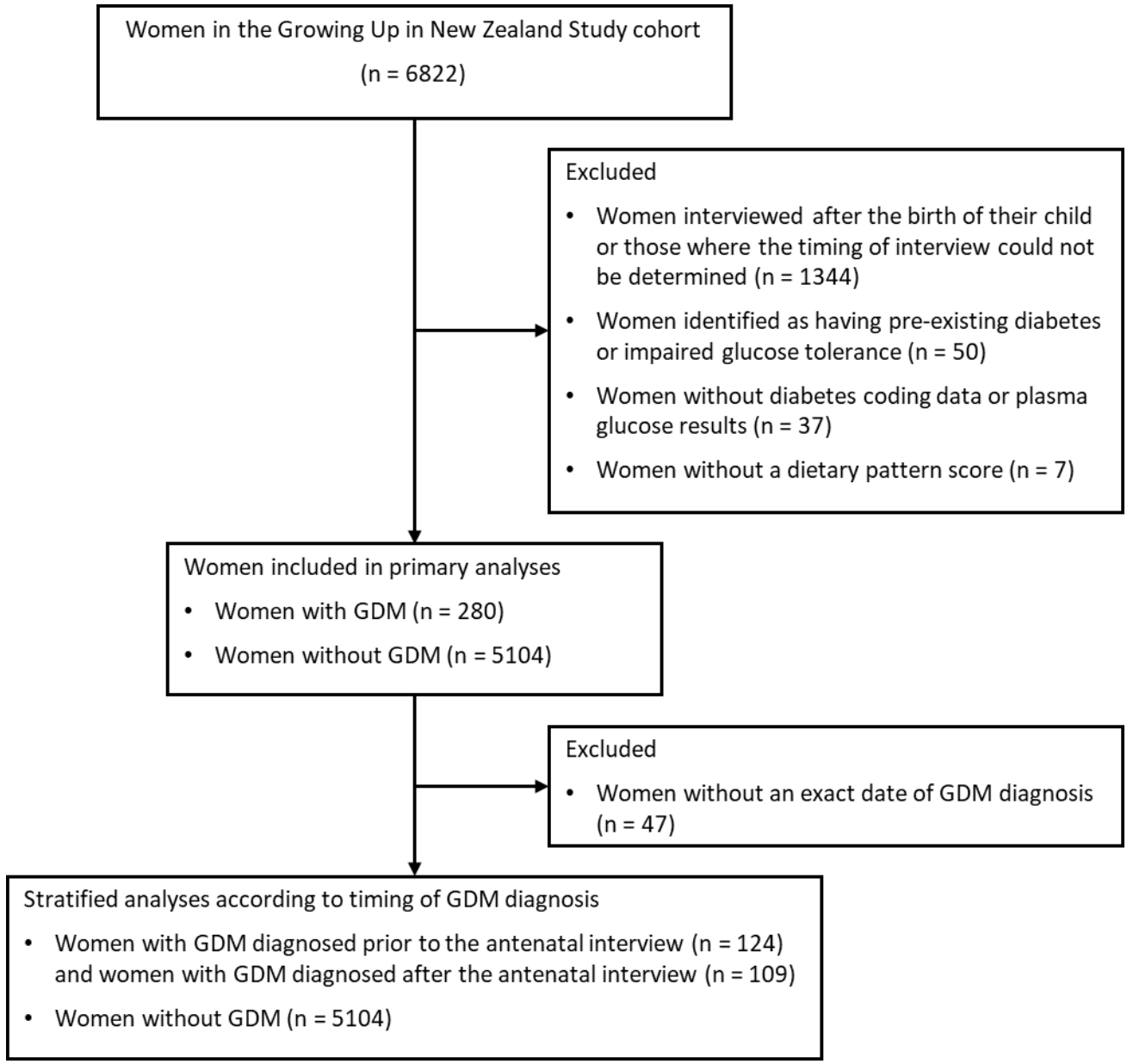

Figure 3. Flowchart showing selection of participants included in primary and secondary analyses of dietary patterns and dietary adaptations in women with and without GDM from the Growing Up in New Zealand study

Table 9. Characteristics of women in the Growing Up in New Zealand cohort according to GDM diagnosis[1]

	Women without GDM	Women with GDM	*p* value
n (%)	5104 (94.8)	280 (5.2)	
Age group (years)			<0.0005
<20	259 (5.1)	<10 (<10)	
20 - 24	747 (14.6)	28 (10.0)	
25 - 29	1267 (24.8)	51 (18.2)	
30 - 34	1616 (31.7)	95 (33.9)	
35 - 39	1039 (20.4)	81 (28.9)	
40 and over	176 (3.4)	20 (7.1)	
Self-prioritised ethnicity			<0.0005
European	2913 (57.2)	103 (36.8)	
Māori	686 (13.5)	22 (7.9)	
Pacific	630 (12.4)	55 (19.6)	
Asian	681 (13.4)	84 (30.0)	
Other	186 (3.6)	16 (5.7)	
Parity			0.628
First child	2167 (42.5)	123 (43.9)	
Subsequent child	2937 (57.5)	157 (56.1)	
Pregnancy planning			0.857
Planned	3144 (61.8)	171 (61.3)	
Unplanned	1941 (38.2)	108 (38.7)	
Fertility treatment			0.090
Yes	299 (9.5)	23 (13.5)	
No	2844 (90.5)	148 (86.5)	
Fertility treatment: fertility awareness & weight loss			0.169
Yes	26 (8.7)	<10 (<20)	
No	272 (91.3)	19 (82.6)	
Socioeconomic deprivation			0.021
1 to 2 (least deprived)	864 (16.9)	30 (10.7)	
3 to 4	978 (19.2)	45 (16.1)	
5 to 6	909 (17.8)	61 (21.8)	
7 to 8	1050 (20.6)	63 (22.5)	
9 to 10 (most deprived)	1301 (25.5)	81 (28.9)	
Highest education			0.266
No secondary school	319 (6.3)	14 (5.0)	
Secondary school / NCEA[2] 1 - 4	1187 (23.3)	77 (27.6)	
Diploma/Trade certificate / NCEA[2] 5 - 6	1550 (30.4)	76 (27.2)	
Bachelor's degree	1178 (23.1)	58 (20.8)	
Higher degree	861 (16.9)	54 (19.4)	
Pre-pregnancy BMI (Kg/m^2)			<0.0005
<18.5	192 (4.2)	<10 (<10)	
18.5 - 24.9	2558 (56.2)	103 (41.4)	
25 - 29.9	1034 (22.7)	60 (24.1)	
30 and over	767 (16.9)	79 (31.7)	
Gestational weight gain			0.005

Gained ≥5 Kg	4455 (88.9)	229 (83.0)	
Gained <5 Kg	376 (7.5)	32 (11.6)	
No change	43 (0.9)	<10 (<10)	
Lost <5 Kg	74 (1.5)	10 (3.6)	
Lost ≥5 Kg	62 (1.2)	<10 (<10)	
Actively dieting pre-pregnancy	1272 (24.9)	104 (37.1)	<0.0005
Pre-pregnancy dieting weight loss			0.300
Yes	1032 (82.7)	81 (78.6)	
No	216 (17.3)	22 (21.4)	
Physical activity[3]			
Physically active pre-pregnancy	2578 (50.5)	119 (42.5)	0.009
Physically active during first trimester	1459 (28.6)	62 (22.1)	0.020
Physically active during second & third trimesters	1147 (22.5)	59 (21.1)	0.584
Smoking patterns			0.012
Continued smoking during pregnancy	508 (10.0)	13 (4.6)	
Stopped smoking during pregnancy	494 (9.7)	31 (11.1)	
Non-smoker	4088 (80.3)	236 (84.3)	
Alcohol consumption			<0.0005
Any drinking during pregnancy	1536 (30.1)	42 (15.0)	
Stopped drinking during pregnancy	2276 (44.6)	100 (35.7)	
Non-drinker	1287 (25.2)	138 (49.3)	

n number, *BMI* Body Mass Index, *GDM* gestational diabetes mellitus, *NCEA* National Certificate of Educational Achievement. Data presented as number of participants (percentages), missing values have not been included in the column %. [1]Includes only women interviewed before the birth of their child and excludes women with other forms of diabetes or for whom diabetes status could not be determined or those without dietary pattern scores; [2]NCEA is the primary national qualification for secondary school students in New Zealand; [3]Engaged in moderate or vigorous physical activity for at least 150 minutes per week.

Table 10. Dietary pattern scores among women with and without GDM

Dietary pattern	**Women without GDM** n= 5104	**Women with GDM** n= 280	***p* value**
Junk	0.02 (1.01)	-0.28 (0.95)	<0.0005
Health conscious	0.01 (1.00)	-0.11 (0.95)	0.055
Traditional/White bread	0.01 (1.01)	-0.18 (0.93)	0.002
Fusion Protein	-0.02 (0.99)	0.26 (1.09)	<0.0005

Data presented as mean (SD).

Comparing scores in the highest versus the lowest tertile for each dietary pattern showed similar results (Table 11). Women with dietary pattern scores in the highest tertiles of 'Junk' were 62% less likely, and 'Traditional/White bread' 40% less likely to have GDM compared to women in the lowest tertiles. Having a score in the highest tertile of the 'Fusion Protein' dietary pattern almost doubled the likelihood of having a GDM diagnosis in unadjusted analyses. After adjusting for potential confounders (maternal age, ethnicity, socioeconomic deprivation, pre-pregnancy BMI, pre-pregnancy and first trimester physical activity, smoking pattern, alcohol consumption and dietary pattern score on alternative dietary patterns), women with scores in the highest tertiles of the 'Junk' and 'Traditional/White bread' dietary patterns were half as likely to have a

diagnosis of GDM compared to women with scores in the lowest tertiles. The higher likelihood of GDM for those with scores in the highest tertile of the 'Fusion Protein' dietary pattern compared to the lowest tertile was attenuated and no longer statistically significant in the adjusted model. The 'Health conscious' dietary pattern was not significantly associated with GDM in both the unadjusted and adjusted models when comparing women with scores in the highest versus the lowest tertiles; however, the relationship of a reduced likelihood of GDM in the unadjusted model was reversed to an increased likelihood of GDM in the adjusted model.

Table 11. Unadjusted and adjusted odds of having GDM for women with intakes in the highest tertile compared to those with intakes in the lowest tertile of each dietary pattern

Dietary pattern	**n**	**OR (95% CI)**	***p* value**	**n**	**aOR (CI)**	***p* value**
Junk	3581	0.38 (0.28, 0.52)	<0.0005	3154	0.49 (0.34, 0.70)	<0.0005
Health conscious	3580	0.80 (0.60, 1.08)	0.141	3134	1.24 (0.87, 1.77)	0.244
Traditional/White bread	3597	0.60 (0.44, 0.81)	0.001	3157	0.47 (0.32, 0.68)	<0.0005
Fusion Protein	3589	1.93 (1.42, 2.62)	<0.0005	3160	1.25 (0.87, 1.81)	0.231

Odds ratio (OR) (95% CI) from unadjusted logistic regression; adjusted odds ratio (aOR) (95% CI) from adjusted logistic regression (maternal age group, ethnicity, socioeconomic deprivation, pre-pregnancy BMI, pre-pregnancy and first trimester physical activity, smoking, alcohol consumption and dietary patterns included in the model).

In analyses stratified according to the timing of GDM diagnosis, the relationship between higher scores on 'Junk' and 'Traditional/White bread' dietary patterns with a reduced likelihood of GDM strengthened when comparing women without GDM to women with GDM diagnosed before the antenatal interview (Table 12). In analyses comparing women diagnosed with GDM after the antenatal interview to women without GDM, only the association of a higher score on the 'Junk' dietary pattern with a reduced likelihood of GDM diagnosis remained significant, although this was attenuated.

Table 12. Adjusted odds of having GDM for women with intakes in the highest tertile compared to those with intakes in the lowest tertile of each dietary pattern stratified according to timing of diagnosis

	GDM diagnosed before interview			**GDM diagnosed after interview**		
Dietary pattern	**n**	**aOR (CI)**	***p* value**	**n**	**aOR (CI)**	***p* value**
Junk	3050	0.27 (0.15, 0.50)	<0.0005	3037	0.54 (0.30, 0.96)	0.036
Health conscious	3043	0.95 (0.54, 1.68)	0.860	3035	1.44 (0.81, 2.58)	0.214
Traditional/White bread	3072	0.21 (0.12, 0.38)	<0.0005	3045	0.64 (0.35, 1.18)	0.153
Fusion Protein	3062	1.13 (0.64, 1.99)	0.676	3055	0.67 (0.38, 1.18)	0.169

Adjusted odds ratio (aOR) (95% CI) from adjusted logistic regression (maternal age group, ethnicity, socioeconomic deprivation, pre-pregnancy BMI, pre-pregnancy and 1st trimester physical activity, smoking, alcohol consumption & dietary patterns included in the model).

Differences in the types of foods or drinks avoided or added due to pregnancy between women with and without GDM and between women diagnosed before or after the antenatal interview are shown in Table 13. Significantly more women with GDM avoided chocolate, foods high in fat or sugar and soft drinks and added

milk or milk products to their diets during pregnancy compared to women without GDM. Significantly more women with GDM diagnosed before the antenatal interview avoided high fat or sugar foods and added milk or milk products compared to women with GDM diagnosed after the antenatal interview.

Table 13. Foods and drinks avoided or added during pregnancy

	Women without GDM	**Women with GDM**	**GDM diagnosed before interview**	**GDM diagnosed after interview**
Foods/drinks avoided	n=4456	n=241	n=104	n=96
Chocolate	29 (0.7)	<10 (<10)[a]	<10 (<10)[a]	<10 (<10)[a]
High fat or sugar foods	252 (5.7)	61 (25.3)[a]	37 (35.6)[a,b]	11 (11.5)[a,b]
Alcohol	2876 (64.5)	109 (45.2)[a]	52 (50.0)[a]	42 (43.8)[a]
Soft drinks	742 (16.7)	78 (32.4)[a]	30 (28.8)[a]	33 (34.4)[a]
Foods/drinks added	n=2129	n=116	n=50	n=48
Vegetables and fruit	108 (5.1)	<10 (<10)	<10 (<10)	<10 (<10)
Breads and cereals	126 (5.9)	<10 (<10)	<10 (<20)	<10 (<10)
Milk or milk products	779 (36.6)	62 (53.4)[a]	32 (64.0)[a,b]	21 (43.8)[b]
Lean meat, chicken, seafood, eggs, cooked dried beans or peas	766 (36.0)	45 (38.8)	18 (36.0)	23 (47.9)
Fluids	831 (39.0)	28 (24.1)[a]	10 (20.0)[a]	13 (27.1)
Supplements	446 (20.9)	24 (20.7)	<10 (<20)	12 (25.0)
Other	337 (15.8)	13 (11.2)	<10 (<20)	<10 (<10)

Data presented as number of participants (percentages), missing values have not been included in the column %; [a]Significantly different in women with GDM compared to women without GDM (p<0.05); [b]Significantly different between women with GDM diagnosed before vs after the antenatal interview (p<0.05).

Almost three-quarters (71.6%) of women reported receiving information that resulted in making changes to their diet. Sources of information leading to dietary change in women with and without GDM are presented in Table 14. Significantly more women with GDM reported receiving information from a dietitian or nutritionist or an obstetrician and significantly fewer from friends, antenatal class, or books, magazines and newspapers compared to women without GDM. Compared to women without GDM, the magnitude of these differences were greater in women with GDM diagnosed before the antenatal interview than those with GDM diagnosed after the antenatal interview. Almost eight times more women with GDM diagnosed before the antenatal interview reported receiving information from a dietitian or nutritionist compared to women with GDM diagnosed after the antenatal interview.

Table 14. Information leading to dietary changes

	Women without GDM	Women with GDM	Women with GDM diagnosed before interview	Women with GDM diagnosed after interview
n	5100	280	124	109
Received information leading to dietary changes	3652 (71.6)	215 (76.8)	98 (79.0)	83 (76.1)
Sources of information				
Family/whānau	873 (23.9)	36 (16.7)	14 (14.3)[a]	16 (19.3)
Friends	853 (23.4)	30 (14.0)[a]	15 (15.3)	11 (13.3)[a]
GP	1274 (34.9)	71 (33.0)	31 (31.6)	29 (34.9)
Midwife	2703 (74.1)	151 (70.2)	62 (63.3)[a]	63 (75.9)
Obstetrician	273 (7.5)	27 (12.6)[a]	16 (16.3)[a]	<10 (<20)
Dietitian or nutritionist	61 (1.7)	58 (27.0)[a]	46 (46.9)[a,b]	<10 (<10)[a,b]
Alternative health practitioner	58 (1.6)	<10 (<10)	<10 (<10)	<10 (<10)
Antenatal class	247 (6.8)	<10 (<10)[a]	<10 (<10)[a]	<10 (<10)
The internet	681 (18.7)	33 (15.3)	13 (13.3)	17 (20.5)
Radio	26 (0.7)	<10 (<10)	<10 (<10)	<10 (<10)
TV	123 (3.4)	<10 (<10)	<10 (<10)	<10 (<10)
Books, magazines, newspaper	1117 (30.6)	48 (22.3)[a]	18 (18.4)[a]	25 (30.1)
Other	127 (3.5)	10 (4.7)	<10 (<10)[b]	<10 (<10)[b]

Data presented as number of participants (percentages), missing values have not been included in the column %; [a]Significantly different between women with GDM compared to women without GDM (p<0.05); [b]Significantly different between women with GDM diagnosed before versus after the antenatal interview (p<0.05).

Discussion

In this cohort of New Zealand women, we found women with a diagnosis of GDM had significantly lower adherence to 'Junk' and 'Traditional/White bread' dietary patterns compared to women without a diagnosis of GDM. These findings are in contrast to a number of studies exploring dietary patterns associated with GDM (Donazar-Ezcurra et al., 2017; Schoenaker et al., 2015; Sedaghat et al., 2017; Zhang, Schulze, et al., 2006) in which dietary patterns characterized by higher intakes of processed meats, fried foods, cakes and biscuits, confectionary, jams, full fat dairy and salty snacks, similar to the 'Junk' and 'Traditional/White bread' dietary patterns identified in the GUiNZ cohort, have been associated with an increased risk of GDM. Together with our finding that a significantly greater proportion of women with GDM than of those without GDM reported receiving information from a dietitian or nutritionist or obstetrician and avoiding foods or drinks high in fat or sugar, these results are strongly suggestive of a treatment effect. This is particularly evident when looking at stratified analyses according to timing of diagnosis in which these relationships were strongest in women diagnosed with GDM before the antenatal interview compared to those diagnosed after, suggesting that these women with GDM are likely to have received advice on the management of GDM and made dietary adaptations prior to the completion of the food frequency questionnaire.

Diet is considered pivotal in the management of GDM (American Diabetes Association, 2019b; Metzger et al., 2007; Simmons et al., 2008) and New Zealand guidelines recommend women with a diagnosis of GDM are referred to a specialist diabetes in pregnancy service where they receive specialist care from a multidisciplinary team, including input from a dietitian and obstetrician (Ministry of Health, 2014). Dietary guidelines for the management of GDM frequently recommend a low glycaemic index diet or the avoidance of simple sugars (American Diabetes Association, 2015a; Dietitians New Zealand, 2010, 2016; International Diabetes Federation, 2009; National Institute for Health and Care Excellence, 2015) and some encourage a reduction in saturated fats (Dietitians New Zealand, 2010, 2016; Ministry of Health, 2014). In our previous work exploring dietetic practice in the management of GDM, dietitians frequently reported discussing healthy eating, core food group requirements, carbohydrate quantity and distribution, simple sugars and fat with women with GDM (Lawrence, Wall, Bloomfield, & Crowther, 2016). These recommendations are consistent with the changes women reported making to their diets and the differences seen in dietary patterns. For example, advice to limit intake of simple carbohydrates and saturated fats could result in lower scores on the 'Junk' and 'Traditional/White bread' dietary patterns as foods with these characteristics had high factor loadings in these patterns. Similarly, associations of higher intakes on the 'Fusion/Protein' dietary patterns in women with GDM diagnosed before the antenatal interview could be due to the foods with high factor loadings in this pattern being noodles, rice, or pasta (potentially low glycaemic index foods), seafood, chicken, red meat, eggs and green leafy vegetables, which women may have been encouraged to consume when receiving dietary advice for GDM. The 'Health Conscious' dietary pattern included high factor loadings for dried fruits and non-citrus fruits, which some women may limit after learning of their diagnosis of GDM due to the sugar content of these foods. This may partly explain non-significant and inconsistent findings for this dietary pattern. The smaller proportion of women avoiding soft drink in those with GDM diagnosed before the antenatal interview compared to those diagnosed after the antenatal interview could be explained by the finding that dietitians in New Zealand frequently provide advice on artificial sweeteners (Lawrence et al., 2016). It is possible that women receiving this type of advice choose artificially sweetened soft drinks rather than avoiding them. Dietitians in our survey of dietetic practice also commonly reported discussing calcium and core food group requirements with women with GDM (Lawrence et al., 2016), consistent with a greater proportion of women with GDM reporting adding milk and milk products to their diets.

The relationship between higher adherence to the 'Junk' and 'Traditional/White bread' dietary patterns and a reduced likelihood of having a diagnosis of GDM, even in analyses including only women with GDM diagnosed after the interview and, therefore, presumably unaware of their diagnosis, may be explained by the finding that there was still a greater proportion of women diagnosed with GDM after the interview who reported receiving information from a dietitian or nutritionist compared to women without GDM. In our survey of dietetic practice in the management of GDM, 76% of dietitians reported that women had already received nutrition information prior to their first encounter with a dietitian (Lawrence et al., 2016). Furthermore, a greater proportion of

women with GDM reported a pre-pregnancy BMI in the overweight and obese category, receiving fertility treatment, including weight loss advice, and to be actively dieting pre-pregnancy compared to women without GDM. It is possible that women with GDM may have been identified or self-identified as having risk factors for GDM or other pregnancy complications and were therefore already actively making changes to their diets prior to receiving a diagnosis of GDM.

The diagnosis of GDM has been described as a 'teachable moment', in which a diagnosis of GDM may motivate women to make health-related behaviour changes (Okely, Mason, Collier, Dunnachie, & Swanson, 2019). These findings and ours are supported by studies in which nutrition counselling in pregnant women with or at risk of GDM have resulted in favourable dietary changes (Kinnunen et al., 2014; Korpi-Hyovalti et al., 2012; Morisset et al., 2014). In a cluster-randomized controlled trial, Kinnunen et al. (2014) investigated the impact of intensified dietary counselling on food habits of 399 women at risk of GDM. The intervention consisted of five individual counselling sessions on gestational weight gain, physical activity and diet by public health nurses during routine visits to maternity clinics in Finland and resulted in improvements in consumption of fruit and vegetables, high fibre bread and low-fat cheese and in the quality of dietary fat intake when compared to women in the usual care group (Kinnunen et al., 2014). In a group of Canadian women, 17 with GDM and 27 with normal glucose tolerance, Morisset et al. (2014) demonstrated that a multidisciplinary medical and nutrition intervention, including counselling from a registered dietitian, was effective in the achieving prescribed macronutrient distributions and controlling gestational weight gain in women with GDM (Morisset et al., 2014). Other studies have demonstrated further benefits of dietetic input in women with GDM, including reduced insulin use and improvements in glycated haemoglobin (Reader et al., 2006) and reduced likelihood of infant admission to neonatal intensive care or special care units (Absalom, Zinga, Margerison, & van der Pligt, 2019).

Strengths of this study include the large, ethnically diverse sample size and the availability of information on factors likely to impact on dietary intake such as sources of information leading to dietary change during pregnancy. In the comparisons of women with GDM diagnosed before and those diagnosed after the antenatal interview, only women with a GDM diagnosis according to laboratory results were included in analyses, as clinical coding data did not include the exact date of diagnosis. A limitation to our findings is that data were not collected on actual input received during pregnancy to confirm our hypotheses. We also had insufficient data on history of GDM in a previous pregnancy to determine whether this may have contributed to dietary changes during the pregnancy reported on during this study.

Conclusions

Our study found women with GDM had significantly lower adherence scores on 'Junk' and 'Traditional/White bread' dietary patterns compared to women without GDM. A greater proportion of women with GDM avoided

foods and drinks high in fat or sugar and reported receiving dietary information from a dietitian or nutritionist or an obstetrician compared to women without GDM. Women with GDM appear to make significant changes their diet during pregnancy, most likely as a result of advice from healthcare professionals.

Chapter 4

Dietetic management of GDM in New Zealand

This chapter has been published as a peer review journal article:

Lawrence RL, Wall CR, Bloomfield FH, Crowther CA. (2016). Dietetic management of gestational diabetes in New Zealand: A cross-sectional survey. Nutrition & Dietetics 73(5): 95 - 104

Dietetic management of gestational diabetes in New Zealand: A cross-sectional survey

Introduction

GDM is characterised by insulin resistance and elevated blood glucose concentrations first diagnosed in pregnancy (Setji, Brown, & Feinglos, 2005; World Health Organization, 2013). GDM affects between two and 17% of pregnancies worldwide (Hunt & Schuller, 2007) and is diagnosed in over 3,000 pregnant women annually in New Zealand (Ministry of Health, 2014). Rates of GDM are increasing both in New Zealand (National Women's Health, 2015) and internationally (Ferrara, 2007). GDM is associated with significant health and economic costs (Danyliv et al., 2014). Adverse pregnancy and neonatal outcomes associated with GDM, such as preeclampsia, macrosomia, shoulder dystocia and neonatal hypoglycaemia, are a result of raised blood glucose concentrations (González-Quintero et al., 2007; The HAPO Study Cooperative Research Group, 2008; Vambergue et al., 2002). Whilst for some women glucose tolerance returns to normal after pregnancy, women with GDM remain at increased risk for developing GDM in future pregnancies and over half will develop type 2 diabetes within 10 years after giving birth (Bellamy, Casas, Hingorani, & Williams, 2009; Kim, Newton, & Knopp, 2002). Infants born to women with GDM also face an increased lifelong risk of obesity, the metabolic syndrome and diabetes (Boney et al., 2005; Cho et al., 2000).

Diet is recognized as an essential part of GDM management which can lead to improved pregnancy outcomes (Crowther et al., 2005; Landon et al., 2009) and medical nutrition therapy is advocated as the primary therapy for GDM (American Diabetes Association, 2004; Metzger et al., 2007; Simmons et al., 2008). Medical nutrition therapy for GDM aims to meet the nutritional requirements of pregnancy for the birth of a healthy infant whilst maintaining normal glycaemia in order to reduce the complications associated with GDM and meet the specific needs of the individual (Canadian Diabetes Association & Dietitians of Canada, 2006; Dyson et al., 2011). A number of dietary strategies have been identified to aid glycaemic control (Moses et al., 2009; Sievenpiper & Dworatzek, 2013) and a number of international practice guidelines exist to guide nutrition therapy (Academy of Nutrition and Dietetics, 2014; American Diabetes Association, 2015b; Canadian Diabetes Association & Dietitians of Canada, 2006; Dietitians New Zealand, 2010; Dyson et al., 2011; Health Service Executive Ireland, 2010; International Diabetes Federation, 2009; Metzger et al., 2007; Ministry of Health, 2014; National Institute for Health and Care Excellence, 2015; Negrato et al., 2010; Scottish Intercollegiate Guidelines Network, 2014; Thompson et al., 2013).

Many international bodies recommend all women with GDM are seen by a dietitian for dietary advice (Academy of Nutrition and Dietetics, 2014; American Diabetes Association, 2015b; Canadian Diabetes Association & Dietitians of Canada, 2006; Dyson et al., 2011; Health Service Executive Ireland, 2010; Hoffman, Nolan, Wilson,

Oats, & Simmons, 1998; Ministry of Health, 2014; National Institute for Health and Care Excellence, 2015; Negrato et al., 2010; Scottish Intercollegiate Guidelines Network, 2014). However, there is little published literature evaluating best practice in the dietetic management of GDM internationally. Two surveys of dietitians working with women with GDM in Australia and Malaysia have found inconsistencies in dietetic management of GDM and a need for locally relevant, evidence-based practice guidelines for a systematic approach to dietary interventions and follow-up in women with GDM (Farhanah et al., 2014; Morrison et al., 2011). With today's abundance of publicly available and often conflicting information on nutrition, a consistent and evidence-based approach is important to protect the health of pregnant women and their infants and to instil confidence in the advice provided by healthcare professionals (Gray & Gray, 2002; Szwajcer, Hiddink, Koelen, & van Woerkum, 2005).

Current guidelines for the nutritional management of GDM in New Zealand (Dietitians New Zealand, 2010) are not widely accessible. Practices of dietitians providing dietary advice to women with GDM and the extent to which evidence-based practice guidelines are applied are unknown. National guidelines for the nutritional management of GDM are currently under development, yet it has not been documented what information dietitians currently use to inform their practice in GDM, whether dietitians in New Zealand feel there is a need for New Zealand specific guidelines or what dietitians feel these guidelines should contain.

The aims of this study were to establish what dietetic services are provided for women with GDM in New Zealand, evaluate current dietetic practice in the management of GDM, compare this to national and international evidence-based practice guidelines and determine the perceived need for New Zealand-specific evidence-based guidelines for the nutritional management of GDM.

Methods

A 64-item cross-sectional, online survey (Appendix 2) was designed based on the *Gestational Diabetes Dietetic Practice Survey* developed by Morrison et al. (2011) (Appendix 3) and incorporated questions arising from recommendations of New Zealand based guidelines on the management of GDM and food and nutrition guidelines for healthy pregnant women (Ministry of Health, 2006, 2014). Survey questions were presented in three subsections: demographics, GDM service, and GDM practice. Participants were given the opportunity to make additional comments for 22 questions and once again at the end of the survey. The survey incorporated closed and multi-choice questions for those pertaining to demographics, GDM service provision and dietetic practice. Open questions were used for those relating to the need for New Zealand-specific evidence-based guidelines for the nutritional management of GDM and for additional comments. A Likert scale was used for a question on confidence in providing dietary advice for the management of GDM. The survey was pre-tested on 10 New Zealand registered dietitians and adapted based on respondent feedback. New Zealand registered dietitians involved in the care of women with GDM were invited to complete the survey through an

advertisement in the Dietitians New Zealand weekly newsletter and an invitation email sent to members of the Dietitians New Zealand Diabetes Special Interest Group, New Zealand District Health Board Dietetic Departments and Dietetic Private Practices within New Zealand. The online survey was open for six weeks from 17th August to 27th September 2015. Responses to the survey were anonymous. Dietitians not registered or practising in New Zealand, or who did not provide dietary advice for women with GDM were not eligible to be included. The survey response rate was calculated by dividing the number of participants who completed the survey by the estimated number of dietitians who provide care for women with GDM in New Zealand. The total number of dietitians who see women with GDM in New Zealand was estimated after discussion with each District Health Board dietetic department and relevant private practices in New Zealand about how many dietitians in their department or practice provided advice for women with GDM. Ethical approval was granted by the University of Auckland Human Participants Ethics Committee. Participation in the survey was taken as implied consent.

Statistical analysis was performed using SPSS version 21. Data were checked for accuracy by evaluating descriptive statistics. Descriptive statistics are reported as frequency out of the total number of responses for each question (%), mean ± standard deviation (SD), median and interquartile range (IQR). Percentages are calculated from the total number of responses to each question. The level of service provided (measured by the number of women with GDM referred to dietitians, the number of referrals seen by dietitians, time to first appointment with a dietitian, frequency of appointments with a dietitian) and dietary advice (including number of topics covered, recommendations made, compliance of recommendations with national and international evidence-based guidelines) were compared across geographic regions, in metropolitan versus regional or rural areas, primary area of practice, clinical setting, years of experience in GDM, number of women with GDM seen per month, membership of the Diabetes in Pregnancy Special Interest Group or by sources of information used to inform practice. The Chi squared and Fisher's exact tests were used to analyse frequency data. The distribution of data was checked for normality. The t-test and ANOVA were used to analyse continuous data and Mann-Whitney U test and Kruskal-Wallis test were used for non-parametric data. Statistical significance was taken at p <0.05 level. Methodology was compliant with Strengthening the reporting of observational studies in epidemiology (STROBE) guidelines (von Elm et al., 2007).

Results

A total of 33 eligible dietitians responded to the online survey of dietetic practice in GDM. After discussion with dietetic departments at each District Health Board and relevant private practices across New Zealand, a total of 53 dietitians in New Zealand were identified as seeing women with GDM, giving an estimated survey response rate 62%. Demographic characteristics of respondents are reported in Table 15. Twenty-eight (85%) participants received their dietetic qualification from a New Zealand institution, with 26 (93%) of these respondents gaining their qualification from the same university.

Table 15. Demographic characteristics of survey participants

	Number of participants (n)	Proportion of participants (%) or interquartile range (IQR)
Primary area of practice		
Diabetes	18	55
Antenatal / Obstetrics	1	3
General Clinical	13	39
Paediatrics	1	3
Years working as a dietitian	11	3, 30
Years working in GDM	5	1, 13
Work setting		
Public Hospital	27	82
Specialised Diabetes Service	16	49
Community Health Centre	1	3
Private Practice	2	6
Employment status		
Full-time (≥ 30 hours per week)	24	73
Part-time (< 30 hours per week)	8	24
Consultancy / Contract	1	3
Geographic location		
Upper North Island	13	39
Lower North Island	9	27
South Island	11	33
Geographic type		
Metropolitan / Urban (population >100,000)	14	42
Regional	15	46
Rural / Remote	4	12
Dietitians New Zealand member	30	91
Diabetes in Pregnancy Specialist Interest Group member	14	42
Country of dietetic qualification		
New Zealand	28	85
Overseas	5	15
Experience working abroad	12	36

Frequency is given as number out of the total responses for question (%). Years are given as median (IQR). Percentages do not always add up to 100% as more than one response to some questions was permissible.

Dietetic service provision for women with GDM is shown in Table 16. Reasons for referral to a dietitian included poor glycaemic control (8 (89%)), weight issues (7 (78%)), commencement of oral medication (5 (56%)), commencement of insulin (5 (56%)), pregnancy related issues (3 (33%)) or other reasons (3 (9%)). A greater proportion of dietitians working in the lower North Island (9 (100%)) and South Island (11 (100%)) reported seeing all women with GDM referred for dietetic input compared to dietitians working in the upper North Island (9 (69%) (p = 0.029). All (20 (100%)) dietitians working in regional or rural areas reported that all women referred to them were seen by a dietitian compared to nine (69%) dietitians in metropolitan areas (p = 0.017). The number of women with GDM seen by dietitians ranged from less than one to 80 per month (median 16, IQR 5, 24). Seven (64%) respondents from the South Island saw women with GDM at least three times

compared to one (8%) in the Upper North Island and one (11%) in the Lower North Island (p = 0.005). There were no other significant differences in the level of service provided by geographic regions, in metropolitan versus regional or rural areas, primary area of practice, clinical setting, years of experience in GDM, number of women with GDM seen per month, membership of the Diabetes in Pregnancy Special Interest Group or by sources of information used to inform practice.

Table 16. Dietetic service provision for women with GDM in New Zealand

	Number of participants (n)	Proportion of participants (%)
Are all women with GDM referred to a dietitian?		
Yes	24	73
No	6	18
Unsure	3	9
Are all women who are referred seen by a dietitian?		
Yes	29	88
No	2	6
Unsure	2	6
Time between referral and appointment with dietitian		
< 1 week	13	39
1 < 3 weeks	19	58
3 < 4 weeks	1	3
Type of dietetic services provided		
Individual appointments	33	100
Group sessions	5	15
Telephone / Email / Text	17	52
Number of face-to-face visits with a dietitian		
One	16	50
Two	7	22
Three or more	9	28
Factors affecting frequency of visits with a dietitian		
Dietitian's clinical judgement	29	91
Glycaemic control	22	67
Schedule of appointments with other multidisciplinary team members	19	59
Client's preference	15	47
Use of insulin or oral diabetes medications	14	44
Dietetic staffing levels	13	41
Client's literacy levels	8	25
Cultural background / language	7	22
Service protocol	5	16
Other	4	13

Percentages do not always add up to 100% as more than one response to some questions was permissible. Proportions are calculated based on the total number of responses for each question.

Twenty-five (76%) dietitians reported that women with GDM had received nutrition information prior to their first encounter with a dietitian, four (12%) were unsure, and four (12%) reported that women did not receive nutrition information prior to their first appointment. Dietitians discussed between seven to 30 topics with women with GDM with an average of 21 ± 6 (Figure 4). Dietitians working primarily in diabetes covered

significantly more topics when compared with dietitians working in other clinical areas (24 ± 5 vs. 18 ± 6, p = 0.007). There were no significant differences in the number of topics covered by region, in metropolitan versus regional or rural areas, by clinical setting, years of experience in GDM, number of women with GDM seen per month, Diabetes in Pregnancy Special Interest Group membership or by sources of information used to inform practice.

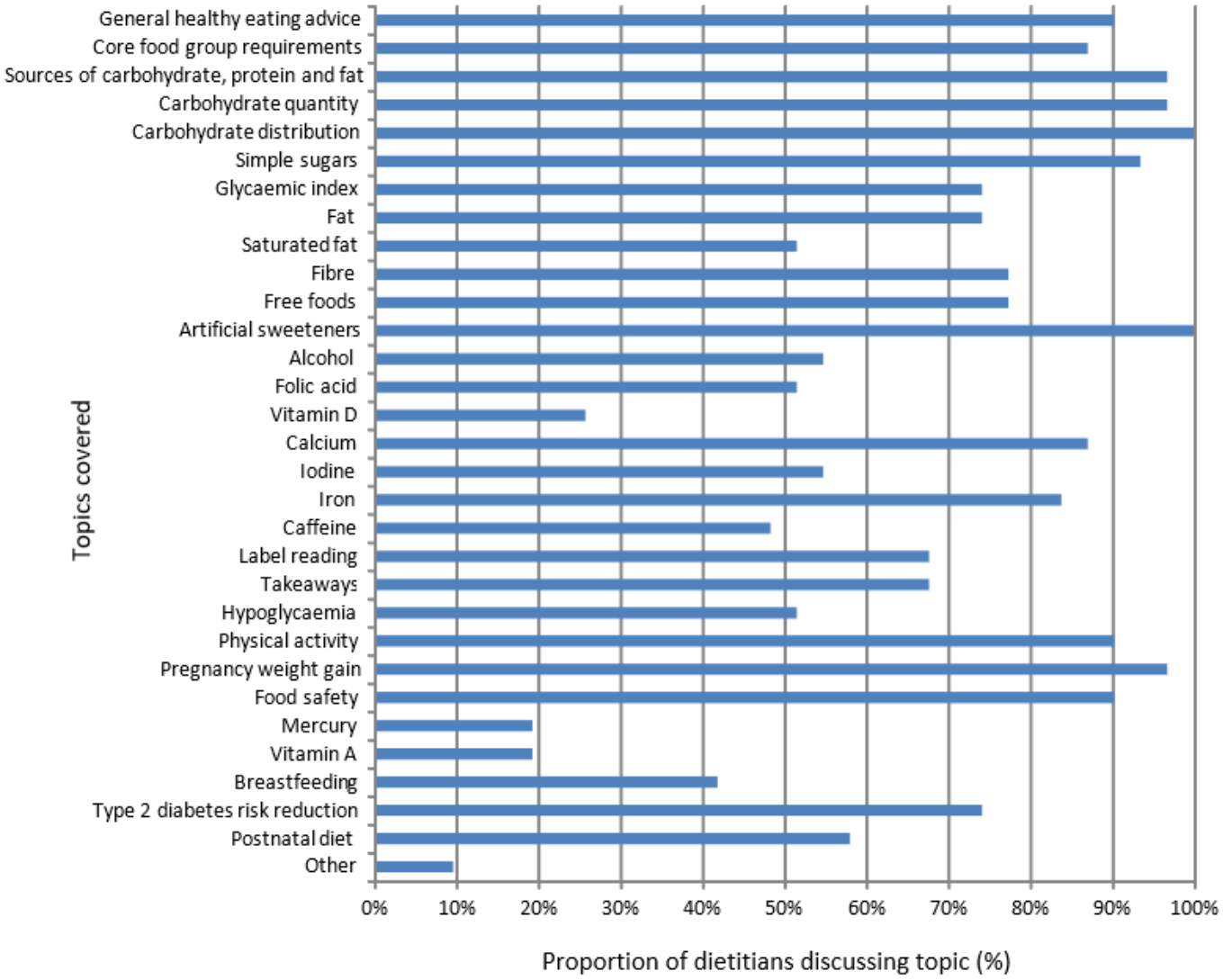

Figure 4. Topics covered by dietitians (n = 31) during dietetic consultations with women with GDM in New Zealand.

Nineteen (61%) dietitians reported giving advice on the number of servings for each of the food groups. Two (7%) dietitians reported recommending specific macronutrient targets as a percentage of total energy, whilst 28 (90%) gave qualitative advice about foods (Figure 5). Nineteen (66%) dietitians gave recommendations on a minimum target for carbohydrate intake ranging from 120 – 240 g per day. Six (32%) dietitians who gave recommendations on targets for carbohydrate intake reported doing so without prescribing a quantity in grams but did so in more general terms such as portions of carbohydrates per day or with a focus instead on the quality

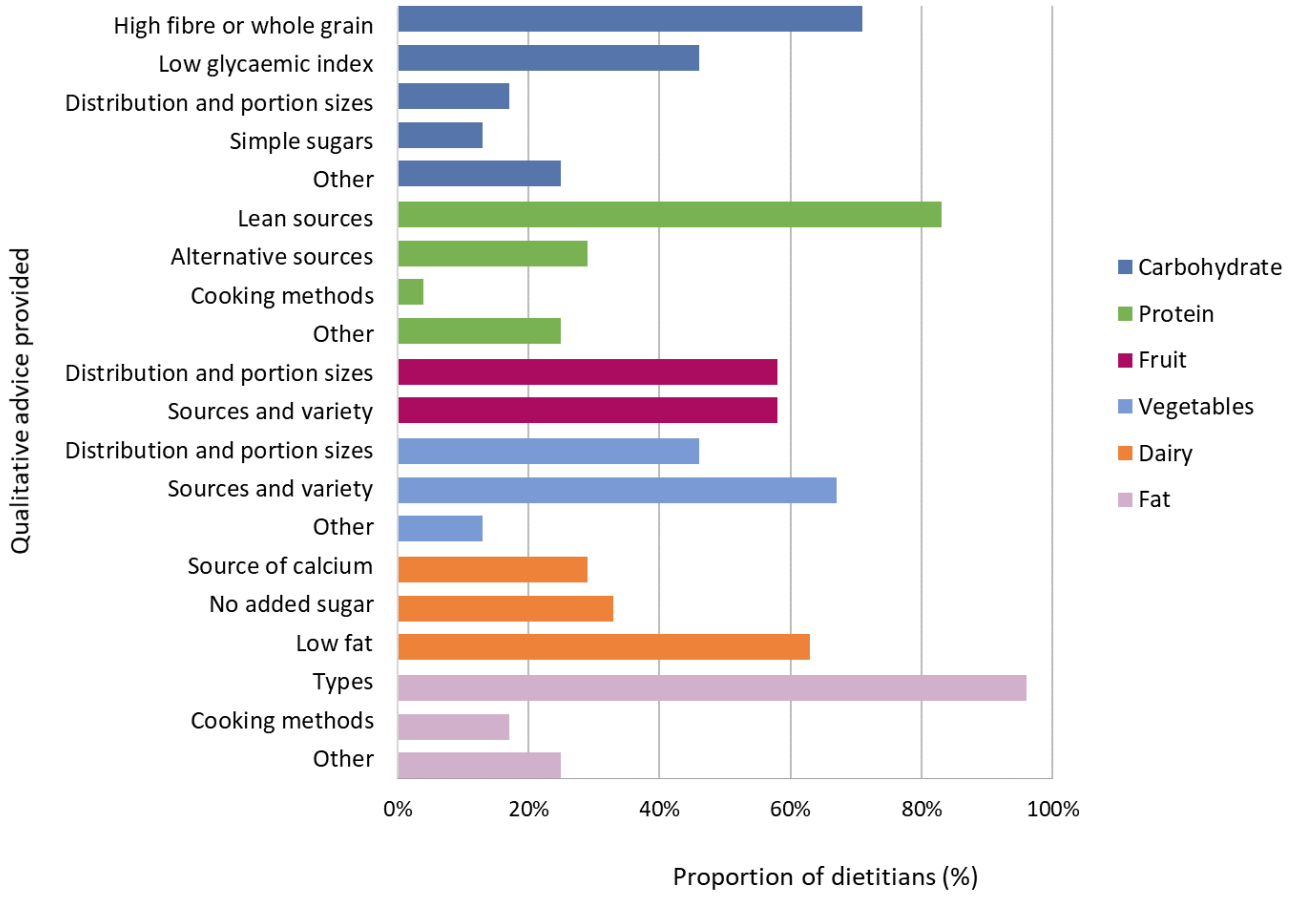

Figure 5. Qualitative advice provided by dietitians (n = 24) to women with GDM in New Zealand for each food group

of carbohydrates. Twenty-one (70%) dietitians gave detailed advice on the glycaemic index. Of the dietitians giving glycaemic index advice, 10 (48%) recommended avoiding high glycaemic index foods, six (29%) recommended including at least one low glycaemic index carbohydrate at each meal, four (19%) recommended that all carbohydrate food should be low glycaemic index, four (19%) gave other glycaemic index advice and two (10%) recommended including at least one low glycaemic index carbohydrate at each meal and snack. All 33 dietitians gave advice on artificial sweeteners with 18 (55%) recommending avoidance of saccharin (954) and cyclamate (952) and use of other sweeteners in small amounts only, six (18%) recommending avoidance of saccharin (954) and cyclamate (952) and use of other sweeteners as desired, and six (18%) recommending use of any sweeteners in small amounts only. Three (9%) dietitians did not specify what advice they gave regarding artificial sweeteners. A greater proportion of dietitians working in a diabetes service recommended women with GDM avoid saccharin (954) and cyclamate (952) and use others in small amounts only compared to dietitians working in a public hospital setting (11 (73%) vs. 7 (47%), p = 0.037). Thirty (91%) dietitians gave advice on gestational weight gain. A greater proportion of dietitians who were members of the Diabetes in Pregnancy Special Interest Group made recommendations on gestational weight gain compared to non-

members (13 (100%) vs. 2 (50%), $p = 0.044$). Twenty-eight (93%) dietitians reported assessing glycaemic control all of whom (100%) reported using the women's blood glucose monitoring booklet, 22 (79%) used the women's notes or other health professional reports, 19 (68%) based the assessment on women's self-report, 19 (68%) used glucometer data, and 3 (11%) used other sources. Fourteen (47%) dietitians reported making recommendations regarding commencement or titration of oral diabetes medication or insulin. There was a significant association between making a recommendation about medication and the number of women with GDM dietitians saw per month (median number of women seen 23 vs. 7 in those making recommendations vs. those not making recommendations, $p = 0.001$). No other significant differences in recommendations made by dietitians were seen.

Twenty-nine (100%) dietitians reported using New Zealand based guidelines and eleven (38%) dietitians also reported using international guidelines to inform their practice in caring for women with GDM. Twenty-five (86%) dietitians reported using the Ministry of Health Food and Nutrition Guidelines for Healthy Pregnant and Breastfeeding women (Ministry of Health, 2006), 23 (79%) the Ministry of Health Screening, Diagnosis and Management of GDM guidelines (Ministry of Health, 2014), 11 (38%) the Auckland Regional Diabetes Dietitians Standard of Care for the Nutritional management of GDM (Dietitians New Zealand, 2010), 10 (34%) the National Institute of Clinical Excellence Guidelines (National Institute for Health and Care Excellence, 2015), eight (28%) the Academy of Nutrition and Dietetics Evidence Based Practice Guidelines (Academy of Nutrition and Dietetics, 2014) and four (14%) reported using other guidelines. Compliance with national and international evidence-based guideline recommendations ranged from 28% to 100% (Table 17). Of those making recommendations on food group servings, 16 (89%) reported using the Ministry of Health Food and Nutrition Guidelines for Healthy Pregnant and Breastfeeding Women (Ministry of Health, 2006) to inform their practice. These guidelines were used by all (3 (100%)) dietitians who made recommendations on minimum fibre intake and by 20 (83%) of those making gestational weight gain recommendations. Of dietitians making recommendations on minimum carbohydrate intake, seven (41%) reported using the Academy of Nutrition and Dietetics guidelines (Academy of Nutrition and Dietetics, 2014). Of those dietitians using the patient's glucometer to assess blood glucose levels, 22 (79%) reported using the Ministry of Health clinical practice guidelines for GDM (Ministry of Health, 2014). There were no differences in the compliance with national and international guidelines by dietitians by region, in metropolitan versus regional or rural areas, primary area of practice, clinical setting, years of experience in GDM, number of women with GDM seen per month, membership of the Diabetes in Pregnancy Special Interest Group or by sources of information used to inform practice.

Table 17. Compliance of recommendations made by dietitians to women with GDM in New Zealand with local and international guidelines[1,2,3]

Recommendation	Number of participants (n)	Proportion of participants (%)
Food group servings[1]	8	42
Carbohydrate (≥6 servings per day)	12	86
Protein (≥2 servings per day)	18	95
Fruit (≥2 servings per day)	19	100
Vegetables (≥4 servings per day)	12	63
Dairy or calcium rich foods (≥3 servings per day)	15	79
Fats and oils (minimal amounts)	6	100
Fibre target (≥22 g per day)[1]	4	100
Gestational weight gain[1]	23	96
Minimum carbohydrate intake (≥175 g per day)[2]	11	65
Glucometer used to assess blood glucose control[3]	22	79
Referrals seen within one week[2]	13	39
At least three dietetic consultations provided[2]	9	28

Proportions are calculated based on the total number of responses for each question. [2]Ministry of Health Food and Nutrition Guidelines for Healthy Pregnant and Breastfeeding Women (2006), [2]Academy of Nutrition and Dietetics GDM guidelines (2014), [3]Ministry of Health clinical practice guidelines for GDM (2014)

Five (16%) dietitians reported that their dietetic service for women with GDM was evaluated. Outcome measures reported to be included in this evaluation were referrals (2 (40%)), glycaemic control (2 (40%)) and gestational weight gain (1 (20%)). Twenty-four (80%) dietitians reported employing strategies to evaluate their own practice in GDM and reported using self-reflection (21 (88%)), peer review (19 (79%)), benchmarking (4 (17%)) and audit (4 (17%)). The majority of respondents reported being confident (17 (57%)) or very confident (9 (30%)) in their management of women with GDM with three (10%) somewhat confident and one (3%) not confident.

Twenty (63%) respondents believed the service within which they worked offered adequate dietetic services for women with GDM, nine (28%) felt the service within which they worked did not offer adequate dietetic services for women with GDM and three (9%) were unsure. When asked "Do you feel the need for New Zealand evidence-based nutrition practice guidelines for GDM?" 25 (76%) dietitians answered yes. Key areas identified for these guidelines to focus on included carbohydrate distribution and minimum carbohydrate requirements (9 (39%)), gestational weight gain (9 (39%)), macronutrient distribution (4 (17%)), and special considerations for different ethnic groups (4 (17%)). Other areas (9 (39%)) included highlighting the importance of dietetic input for women with GDM, guidance on frequency of dietetic input and need for appropriate postnatal follow-up with a dietitian.

Discussion

This survey describes current dietetic practices and services provided to women with GDM in New Zealand and compares these to national and international evidence-based guidelines. While there were consistencies in some aspects of nutrition therapy, a variety of differences existed in service provision and in compliance with evidence-based guidelines.

Only two-thirds of dietitians considered the service within which they worked to offer adequate dietetic services for women with GDM. Not all women with GDM were referred to a dietitian and not all those referred were seen by a dietitian despite local and international guidelines emphasizing the importance of dietetic input for all women with GDM (Academy of Nutrition and Dietetics, 2014; American Diabetes Association, 2019b; Canadian Diabetes Association & Dietitians of Canada, 2006; Dyson et al., 2011; Health Service Executive Ireland, 2010; Ministry of Health, 2014; National Institute for Health and Care Excellence, 2015; Scottish Intercollegiate Guidelines Network, 2014; Thompson et al., 2013). Half of dietitians reported that they saw women only once during their GDM pregnancy, with most seeing women within three weeks of referral. Whilst similar to that found in other studies (Farhanah et al., 2014; Morrison et al., 2011; Wilkinson et al., 2014), this level of service is inconsistent with evidence-based guidelines which have shown improved health outcomes when women with GDM are seen within one week of diagnosis and at least three times during their GDM pregnancy (Reader et al., 2006). A number of women with GDM may therefore be missing appropriate guidance on diet, which has been shown to improve health outcomes for both women with GDM and their infants (Crowther et al., 2005; Landon et al., 2009; Reader et al., 2006).

A large number of topics were covered by dietitians with those working primarily in diabetes covering significantly more topics than dietitians working in other areas. Differences were seen in specific recommendations made and the approach to giving advice. Depending on the recommendation, compliance with evidence-based practice guidelines varied widely. The majority of dietitians gave advice on the number of servings recommended for each food group but less than half of these recommendations complied with Ministry of Health guidelines for pregnant women (Ministry of Health, 2006), despite almost nine in ten of those making these recommendations reporting to use these guidelines to inform their practice. Two thirds of dietitians made recommendations on a minimum carbohydrate intake with recommendations ranging from 120 to 260 g per day. Although there is no set nutrient reference value for carbohydrate in New Zealand (National Health and Medical Research Council; Ministry of Health, 2006), the Institute of Medicine recommends an intake of at least 175 g per day during pregnancy (Institute of Medicine, 2005). It is suggested that adequate energy from carbohydrate is required to prevent the potentially negative effects of ketosis on fetal development (Rizzo, Metzger, Burns, & Burns, 1991); however, high carbohydrate intake can lead to hyperglycaemia which has been associated with increased risk of adverse outcomes in GDM (Jovanovic-Peterson & Peterson, 1991; The HAPO Study Cooperative Research Group, 2008). International guidelines

advise an intake in the range of range of 40 – 45% of total energy intake or up to 50% of total energy intake if from low glycaemic index sources (Academy of Nutrition and Dietetics, 2014; Dietitians New Zealand, 2010; Negrato et al., 2010; Thompson et al., 2013). Almost all dietitians reported making gestational weight gain recommendations that complied with New Zealand Ministry of Health guidelines (Ministry of Health, 2006) and three quarters used glucometers to assess glycaemic control as recommended by the New Zealand Ministry of Health (Ministry of Health, 2014).

Inconsistencies in recommendations made by dietitians may be due to a number of factors. Dietitians reported using a range of sources to inform their practice in caring for women with GDM and over a third of dietitians reported using guidelines developed outside of New Zealand. Differences in available guidelines may contribute to the variation seen in some areas of dietetic practice. For example, different artificial sweeteners are approved for use amongst health and food authorities internationally (Academy of Nutrition and Dietetics, 2014; Canadian Diabetes Association & Dietitians of Canada, 2006; Ministry of Health, 2006) which may explain variance in recommendations in this area. On the other hand, many agencies have adopted the Institute of Medicine's gestational weight gain recommendations (Academy of Nutrition and Dietetics, 2014; Dietitians New Zealand, 2010; Dyson et al., 2011; Ministry of Health, 2014) and almost all dietitians gave advice compliant with these recommendations. Additionally, almost half of dietitians reported their primary area of practice to be in fields other than diabetes. With the breadth of dietetic practice, it can be challenging to keep up-to-date with the latest evidence from all areas (Gray & Gray, 2002). Dietitians for whom GDM makes up only a small proportion of their case load may not have the same resources available to commit to professional development in this area. Up-to-date, locally relevant evidence-based practice guidelines can assist in efficient, evidence-based decision making in such cases (Institute of Medicine, 1990; Myers, Pritchett, & Johnson, 2001). With the increasing prevalence of GDM (Hunt & Schuller, 2007; National Women's Health, 2015) and recognition of the value of diet and lifestyle modification for milder forms or those at risk of GDM (Crowther et al., 2005; Landon et al., 2009; The HAPO Study Cooperative Research Group, 2008), the future impact of GDM on the dietetic workforce is likely to be significant (Koivunen et al., 2015; Ministry of Health, 2014). Evidence-based practice guidelines developed specifically for the New Zealand context could serve as a useful tool for dietitians and other healthcare professionals to implement reliable recommendations. Similar results to ours were seen in surveys of dietetic practice in the management of GDM in Australia and Malaysia (Farhanah et al., 2014; Morrison et al., 2011). Differences in the level of service provided and dietary recommendations made were seen amongst dietitians in both surveys and both authors concluded that results illustrated a need for locally relevant evidence-based practice guidelines for the nutritional management of GDM. There is strong evidence to suggest that well developed evidence-based practice guidelines can lead to improvements in care and patient health when implemented appropriately (Grimshaw et al., 1995; Reader et al., 2006; Wilkinson et al., 2016) and over three quarters of respondents felt there is a need for New Zealand specific evidence-based practice guidelines for the nutritional management of GDM. Dietitians highlighted a number of key areas for which they

felt further guidance is needed including appropriate gestational weight gain, minimum carbohydrate intake and distribution, special consideration for different ethnic groups, the importance of dietetic input for women with GDM, recommended frequency of dietetic input, and appropriate postnatal follow-up.

A limitation of this study was the small sample size which meant it was underpowered to detect small variations in practice. Whilst all efforts were made to distribute the survey to all eligible dietitians it is difficult to ascertain whether any were missed. Nevertheless, from the potentially eligible dietitians identified, the survey had a good response rate. Furthermore, characteristics of survey respondents were comparable to those of the wider dietetic workforce in New Zealand (Ministry of Health, 2011) except that a greater proportion of respondents reported working in a hospital or health service and fewer reported to work in private practice. This is likely due to the focus on dietitians' management of women with GDM and reflects the New Zealand environment where health services for pregnant women are provided free of charge through the public health system. Almost all questions provided an opportunity for additional comments. The survey is therefore likely to be accurate in its description of dietetic practice in New Zealand, the first of its kind in New Zealand.

Conclusions

This survey provides baseline data of current dietetic practice in the management of GDM in New Zealand, highlights differences in dietetic services and practice in the management of GDM in New Zealand, and variation in compliance with local and international evidence-based guidelines. A significant proportion of dietitians feel that current services do not meet the needs of women with GDM. These results strongly support the need for, and could aid the development of, New Zealand-specific evidence-based practice guidelines for the nutritional management of women with GDM. Implementation of these guidelines may lead to greater consistency in care. Guidelines need to be developed using high quality methodology, address specific questions relevant to women with GDM in New Zealand and consider strategies for their implementation in order to enhance uptake by health professionals and ensure optimal care for women with GDM. Further research into how dietitians use evidence-based practice guidelines, how advice is tailored to meet individual client needs, and reasons for lack of referral of some women with GDM to a dietitian may be useful for the development and effective implementation of evidence-based practice guidelines for the nutritional management of GDM in New Zealand.

Chapter 5

Women's experiences of managing gestational diabetes through diet

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New Zealand women's experiences of managing gestational diabetes through diet: A qualitative study

Introduction

During pregnancy, a nutritious diet is important for both the mother's health and the growth and development of the baby (Cox & Phelan, 2008; Hanson et al., 2015). Pregnancy is often referred to as a 'teachable moment' when women are amenable to dietary changes (Phelan, 2010; Szwajcer et al., 2009). However, some view pregnancy as a time when indulgence is acceptable, or even beneficial, as the pregnant woman is 'eating for two' (Kraschnewski & Chuang, 2014). GDM is a form of carbohydrate intolerance first diagnosed in pregnancy (World Health Organization, 2013), which leads to hyperglycaemia and poses significant health risks to both mother and baby. Globally, the prevalence of GDM varies widely (Behboudi-Gandevani et al., 2019) with overall trends showing increasing prevalence (Ferrara, 2007). For women with GDM, poor dietary choices resulting in hyperglycaemia can have harmful consequences (Adams, Li, Nelson, Ogburn, & Danilenko-Dixon, 1998; González-Quintero et al., 2007; Vambergue et al., 2002; Zhu et al., 2016). Diet is well-recognised as the cornerstone of GDM management (Crowther et al., 2005; Landon et al., 2009; Metzger et al., 2007) and referral to a dietitian is recommended for all women diagnosed with GDM (American Diabetes Association, 2019b; Duarte-Gardea et al., 2018; Dyson et al., 2018; Ministry of Health, 2014; National Institute for Health and Care Excellence, 2015; Queensland Clinical Guidelines, 2021). In New Zealand, women with GDM are referred to a multidisciplinary diabetes in pregnancy clinic for management of diabetes (Ministry of Health, 2014). The structure of these clinics varies across New Zealand regions but typically include a diabetes physician, obstetrician, diabetes midwife or diabetes specialist nurse and a dietitian. Although studies have found dietetic input to be associated with positive outcomes for women with GDM (Absalom et al., 2019; Morisset et al., 2014; Reader et al., 2006) surveys of dietetic practice have identified some inconsistencies in the services provided and recommendations made to women with GDM with some women not seeing a dietitian at all (Farhanah et al., 2014; Lawrence et al., 2016; Morrison et al., 2011). Furthermore, women are exposed to nutrition messages from several sources which may be inconsistent or incomplete (de Jersey, Nicholson, Callaway, & Daniels, 2013; Grimes, Forster, & Newton, 2014; Szwajcer et al., 2005; Willcox et al., 2015) leading to confusion about what to do and a lack of confidence in recommendations (Anderson, Hure, Kay-Lambkin, & Loxton, 2014; Neufeld, 2011). GDM is usually diagnosed at 24 to 28 weeks' gestation (Ministry of Health, 2014; World Health Organization, 2013). Thus, women who develop GDM typically need to make several dietary adaptations in a short period to achieve glycaemic control (Carolan et al., 2012; Hui, Sevenhuysen, Harvey, & Salamon, 2014; Parsons et al., 2018). This urgency to master self-management of GDM may be overwhelming for some (Bandyopadhyay et al., 2011; Carolan et al., 2012; Neufeld, 2011; Yee et al., 2016).

There have been international studies exploring women's experiences of GDM, but few have specifically considered the experiences around dietary adaptations (Helmersen, Sørensen, Lukasse, Laine, & Garnweidner-Holme, 2021; Hui et al., 2014; Neufeld, 2011; Yee et al., 2016). As diet is central to a women's management of GDM, a greater understanding of how women perceive dietary advice and how it influences their dietary decisions is important and could help healthcare professionals to tailor care to the needs of women diagnosed with GDM. In this context, we explored New Zealand women's experiences of dietary recommendations following diagnosis with GDM from their perspective. We focused on how women diagnosed with GDM perceive the dietary information given to them and how this information influenced their dietary decisions during pregnancy and beyond.

Methods

Setting and sample recruitment

Participants were purposively recruited (Coyne, 1997) from two large regional health boards in Auckland, New Zealand where the incidence of GDM at the time of recruitment was around 11% (Arrol, 2021; National Women's Health, 2020). A member of the GDM clinic team invited women to participate in the study if they were currently pregnant with a diagnosis of GDM made before 30 weeks' gestation. Guidelines for the diagnosis and management of GDM in New Zealand at the time of the study recommend universal screening for diabetes in pregnancy at the first antenatal visit using HbA1c, with an HbA1c of 50 mmol/mol or above considered to indicate pre-existing undiagnosed diabetes, followed by further screening at 24 to 28 weeks' gestation using either a 50 g-GCT if their early HbA1c was ≤40 mmol/mol or a 75 g-OGTT if early HbA1c was 41 – 49 mmol/mol (Ministry of Health, 2014). A diagnosis of GDM is made if blood glucose values exceed ≥ 11.1 mmol/L after a 1-hour, 50 g-GCT, or if in a 75 g-OGTT fasting glucose is ≥ 5.5 mmol/L or two-hour blood glucose is ≥ 9.0 mmol/L (Ministry of Health, 2014). However, some women present late for the GDM screening test and others are screened early where there is clinical concern. The cut-off for diagnosis before 30 weeks' gestation was chosen after consulting with the lead physician and obstetrician at both district health boards. They both suggested a women's care when diagnosed after 30 weeks' gestation might be different to those diagnosed earlier in pregnancy, 30 weeks would allow time to experience GDM prior to arranging an interview. Women with pre-existing diabetes mellitus, those under the age of 16 years and those unable to adequately understand verbal explanations in English or who had special communication needs were excluded. All women gave written or verbally recorded informed consent. Women were offered a $25 grocery voucher to thank them for their participation in the study.

Data collection and analysis

Data were generated using semi-structured interviews asking about women's experiences of managing GDM through their diet. A semi-structured interview guide (Appendix 4) was developed by a New Zealand Registered

Dietitian with clinical experience in GDM (RL) and a qualitative researcher with a background in nursing (KW). Broad interview questions were used to allow women to describe their experiences in their own words. Prompts elicited further information where necessary. Interviews were conducted between August and December 2019 by RL, who was not involved in the women's care. Participants chose to be interviewed over the telephone, in person at their own home, in a private meeting room or a private space at the GDM clinic. Before commencing the interview, women completed a short demographic questionnaire, which included questions relating to age, ethnicity, gestation, parity, history of GDM in a previous pregnancy and gestation at GDM diagnosis. The New Zealand Deprivation Index (NZDep2013) (Atkinson, Salmond, & Crampton, 2014) was used as a measure of social deprivation using participants' home address. NZDep2013 groups deprivation scores into deciles where 1 represents the least deprived and 10 the most deprived 10% of areas in New Zealand.

Interviews were audio-recorded and transcribed verbatim by RL. Women either chose their own or had a pseudonym allocated to them to preserve their anonymity in the transcripts and reporting of data. Reflexive thematic analysis was chosen as a pragmatic and flexible approach to analysis that is data-driven and not tied to a pre-existing coding framework (Braun & Clarke, 2006, 2020). RL independently coded the data through repeated readings of the transcripts using a general inductive, experiential approach. Ideas or issues raised by participants supported code development. Codes were then grouped into themes that comprised codes of shared meaning connected through a central concept for example, Managing GDM is a balancing act (Braun & Clarke, 2012; Braun & Clarke, 2020). Codes and themes were then discussed with KW, an experienced qualitative researcher, to refine and confirm themes as an authentic reflection of the participants' words.

Data collection and analysis occurred concurrently to allow adaptation of interview questions to follow leads in the data based on information from each subsequent participant. Interviews continued until data saturation was achieved. Data saturation was the point at which, after reviewing coding and theme development from previous interviews, RL and KW agreed that further interviews were unlikely to reveal new information (Braun & Clarke, 2021). Two further interviews were conducted to confirm that data saturation had been achieved. This study was approved by the Auckland Health research Ethics Committee (reference 000121) and reported according to the consolidated criteria framework for reporting qualitative studies (COREQ) (Tong, Sainsbury, & Craig, 2007).

Results

A total of 18 women participated in the study. Women were a median age of 34 years (range 28 – 41 years), from a range of ethnic backgrounds, and half (n=9) were expecting their first baby (Table 18). Most women (n=15) were experiencing GDM for the first time and were diagnosed with GDM for a median of 9.6 weeks

(range 4.0 – 21.7 weeks) before the interview. Half (n=9) of the interviews were conducted in person and half (n=9) over the telephone. Interviews lasted a median of 45 minutes (range 21 - 96 minutes).

Overall, women described the primary objective of dietary advice to be to control their blood glucose levels and **controlling the numbers** was the focus of many women's story. Thematic analysis yielded three intricately intertwined themes that encompassed women's experiences of dietary recommendations and managing their diet to achieve the objective of controlling the numbers (Figure 6).

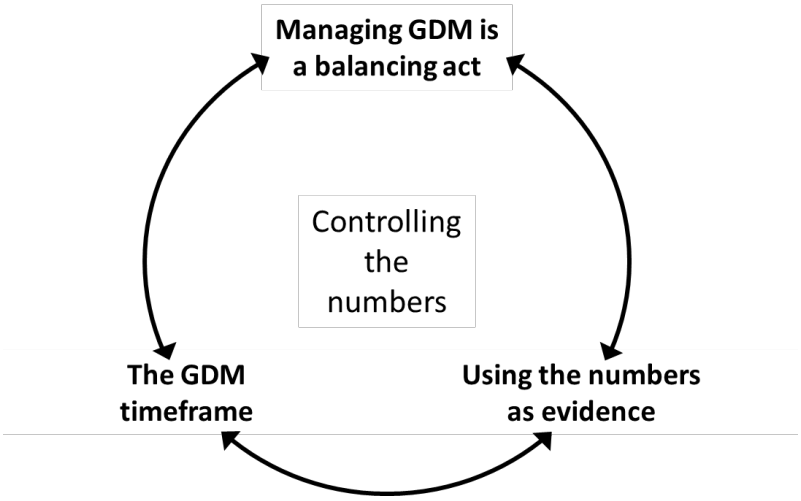

Figure 6. Themes describing women's experiences of managing GDM through diet

Women described *managing GDM as a balancing act* wherein they needed to balance their diet and all the demands of their existing lives with the need to keep their blood glucose readings within the recommended range. Women described using their blood glucose results or *numbers as* "*evidence*" (Nian Zhen): evidence that they really did have GDM or that how they were eating was acceptable or not. Participants frequently described GDM and the dietary adaptations they made to manage this in the context of time or within *the GDM timeframe.* Each theme is described in detail below using participants excerpts to evidence the themes.

Theme 1: Managing GDM is a balancing act

After receiving their diagnosis of GDM, women described needing to find a balance or a way of fitting in the diagnosis and management of GDM with their existing life and preconceived conceptions and understanding of a healthy diet. For some, there was also a need to reconcile their expectations of pregnancy with now having a pregnancy affected with GDM.

Many women described being "shocked" by their diagnosis of GDM despite having risk factors for its development (Amipa, Evergreen, Fei, Mai, Rachel). Even if they were aware of these risk factors, some simply

Table 18. Participant and interview characteristics from the Managing Gestational Diabetes Through Diet study

Participant (pseudonym)	Age	Ethnicity	Socioeconomic deprivation (NZDep2013)	Parity	GDM in previous pregnancy	Gestation at diagnosis (weeks)	Gestation at interview (weeks)	Interview mode	Interview length (minutes)
Amipa	36	Tongan	1	3	Yes	28	35	Telephone	40
Deepti	33	Indian	4	0	-	28	32	Telephone	54
Evergreen	35	Korean	9	0	-	16	37	In-person	32
Fei	36	Chinese	9	1	No	12	21	Telephone	22
Gretchen	32	German	4	0	-	24	31	In-person	72
Huian	35	Chinese	5	1	No	28	37	Telephone	31
Jing	35	Chinese	1	1	Yes	11	24	Telephone	29
Juliana	41	Brazilian	5	0	-	28	36	In-person	37
Kate	30	NZ European	2	2	No	29	35	In-person	68
Mai	35	Vietnamese	10	1	No	26	33	In-person	59
Marama	40	Māori	6	1	No	22	35	Telephone	43
Moeroa	29	Cook Islands Māori	10	0	-	27	31	In-person	34
Nian Zhen	35	Chinese	8	0	-	11	32	In-person	96
Rachel	33	NZ European	8	0	-	26	31	Telephone	33
Rosa	31	Filipino	7	1	No	26	37	Telephone	38
Rose	31	Chinese	2	1	Yes	25	34	In-person	63
Seini	28	Tongan	10	0	-	25	36	Telephone	33
Vishakha	33	Indian	7	0	-	12	28	In-person	29

GDM gestational diabetes mellitus*, NZDep2013* the New Zealand Deprivation Index.

did not believe it would "happen to them" (Fei, Marama, Nian Zhen). Evergreen described the isolation she felt after receiving her diagnosis. She felt she had no one to talk to about having GDM as her Korean cultural upbringing made the subject taboo:

> "my culture background, they don't really tell much about your personal health… For me I feel very alone, because I no one talk, you know. There's only the health professional, that's only person I can rely on."

Some women spoke about grappling with the change in their pregnancy identity as there was a sense that having GDM meant their pregnancy was now "different" (Deepti). There was an undertone of injustice for some women as they felt pregnancy was supposed to be a time where they could indulge and give in to their pregnancy cravings. Gretchen, who was in her first pregnancy, described her feelings of having a GDM affected pregnancy as follows:

> "first of all it's the first pregnancy, and second everyone's saying yeah you have to enjoy that, that's an awesome time and the first thing that you do is to check your blood sugars, you have to check what you're eating, and that's not fun, so it's far away from enjoying the feeling of being pregnant."

Women also expressed feeling alone in their diagnosis as their family or other pregnant women did not have to make the same sacrifices (Jing, Seini, Nian Zhen). Seini spoke of both views saying, family "can be supportive and then at the same time you're kind of on your own… they're eating something different".
Several women described difficulty fitting in the way in which they now needed to eat to manage their GDM with their family norms or expectations:

> "mum is typical Indian and she just like sometimes we can eat other stuff but mum eats roti. So she needs Indian food… it is like hard work because I usually have to cook same food for everyone. Now I have to cook mine different, and my family's different." (Deepti)

Nian Zhen, who had been through some years of fertility treatment, reported a real shift in her priorities at home to manage her GDM, saying she did not "care much about [her] husband taste of food anymore, I just make sure that I have the food, which is gonna be healthy for my baby." Others found a way of balancing what they needed to do to manage GDM whilst still fitting in with the rest of the family. Marama described eating the same as her family, "except when I buy my sugar-free stuff, they're not allowed it." Kate described her accommodation as:

> "I haven't altered really what I make. Like we all eat the same thing, but if I've made like, curry and rice for instance, I'll go heavier on the curry and less on the rice, than everyone else will. I don't want to be making stuff that's not healthy for everyone else just because they don't have gestational diabetes."

A number of women described a degree of dissonance between the information they received from healthcare professionals and their pre-existing beliefs or what they had researched themselves. Some described needing to find a middle-ground or "strike a happy balance" (Rosa) when they were not entirely comfortable with the information received. Others, over time, came to accept that the information provided was correct or in their best interests. Marama said, "I didn't think I was that bad of an eater. And I thought, I, I didn't [need to] make as much changes as I did. But yeah. Not that healthy after all!"

Some women struggled with the advice they had received, particularly with fitting it in with their existing lifestyles or cultural norms and reported feeling that the advice was not particularly "relevant" (Kate) to them as an individual or to their culture. Amipa felt the information she received was "not for a Pacific woman." Rose added:

> "I think some of the food like I can't, like I never tried… That, like they recommend oh this is you know, combined with vegetables and blah blah and uh this is balanced diet, I say but you know we eat rice."

Indeed, Amipa, in her second pregnancy affected by GDM, reported seeking and receiving more relevant and practical information from her Pacific community. Similarly, Rosa, a Filipino women in her second pregnancy, did not fully agree with the advice she received from healthcare professionals, finding information that better suited her from a book, which made more "sense" to her and gave "options" that were closer to her pre-existing diet.

A women's relationship with the healthcare professionals caring for them appeared to influence how they perceived the dietary advice provided and how supported they felt in managing their condition. Some women felt "special" (Vishakha) and genuinely cared for by their healthcare professional. This was particularly evident when women were in close contact with their diabetes midwife or followed up regularly by other healthcare professionals. Juliana described feeling "safer now" because "now that I have this direct contact with the diabetes midwife, it's easier because everything that I eat or if I have some question or anything I just email her and she emails me back."

On the other hand, some women felt like they were "just a number" or "another pregnant woman" to get through (Amipa). It seemed women reported feeling this way when healthcare professionals were not empathetic towards their personal circumstances, details about their care were forgotten, or advice was not

tailored specifically to them. Amipa described two very different experiences with two different healthcare professionals:

> "So you've just been told you need to do this and this and that and that and then show up to this and that alright then bye. There's nothing really special about you as an individual… I was telling [the diabetes midwife] about what is my diet and she was just like oh yup yup, yup, umm, okay so this is what we're gonna do, this is umm, yeah she wasn't really listening like the dietitian that I saw. The dietitian was really good, she was actually really listening, she gave me some feedback, she gave me ideas like how I could change things around which I did."

One factor that seemed to help women find balance in managing GDM was being involved in making decisions about their care and management. Some women even reported feeling trusted in this way and this strengthened the relationship between the woman and healthcare professional. Vishakha described having the "freedom to do so because they could see that I'm actually being honest about my sugar levels."

Theme 2: Using the numbers as evidence

In many ways, women used their blood glucose results as evidence. Evidence that they did have GDM after their initial disbelief that it would happen to them. Evidence that they were doing a good job or "behaving" (Nian Zhen) in terms of their diet. Evidence that the advice provided by healthcare professionals could be trusted, and evidence as to whether they would need to continue to control their diet in the future.

Marama reported thinking her diet "wasn't that bad at first" but after seeing consistently high results in her blood glucose monitoring, she felt this was evidence that she had to start taking her diagnosis "seriously". Once women accepted the need to control their blood glucose, this became the focus of their pregnancy. Women felt the constant need to monitor their blood glucose results made them more "conscious" (Seini) and accountable for what they chose to eat. Universally, women described their motivation to manage GDM as being to ensure the wellbeing of their baby, but the need to control their blood glucose readings became so dominant that the result on their blood glucose meter was frequently their first thought or primary focus, rather than the potential consequences for their baby. Amipa and Rachel both described refraining from indulging because of the possibility of a high reading at their next blood glucose check:

> "'Cos you know like in two hours' time you're going to be checking your sugar levels, so you can't really go pig out on the chocolate cake." (Amipa)

> "I don't want to get a seven or an eight on my blood test after dinner so I'm not going to eat that." (Rachel)

Some women described using their blood glucose readings as evidence that it was acceptable to "cheat" or "sneak in" (Rosa, Gretchen) foods they felt were technically off limits. If the results were still within the recommended range, then this was deemed acceptable:

> "after checking the sugar, that's when I sneak in my, my cheat snack. And it comes with my dinner and then it gets check after dinner with my sugar so far, with everything that I'm eating it's all been maintained." (Rosa)

Similarly, Deepti described using her blood glucose readings to experiment with food as a way to increase the variety of her diet, "the very first week was up and down because I trying what I can eat." On the other hand, women reported feeling frustrated when their blood glucose readings were high for no apparent reason despite their efforts. Kate relayed, "I'll eat the same thing and sometimes the sugar's great and sometimes it's high and I'm like *why* it makes no sense!"

Women also used numbers as evidence that they could trust the healthcare professionals caring for them or the advice they were receiving was trustworthy. Marama reported, "I trust them now" after seeing that the times where she followed healthcare professionals' recommendations were "matching up with when my blood sugars are good." Conversely, Nian Zhen reported being given a pamphlet by the dietitian that she "can't follow" because of high blood glucose readings after consuming the foods listed. She went on to say the glucometer was the only thing she could trust because it would not "cheat on" her.

Theme 3: The GDM timeframe

Timing and the timebound nature of pregnancy and GDM featured in many women's narrative. For many women managing GDM involved sticking to a timetable of eating meals and testing blood glucose levels at certain times of the day and that this was something you "got used to" over time (Gretchen, Amipa, Deepti, Moeroa). For some, the changes they made to their diet to manage GDM was made easier by knowing there was "an end to it" (Juliana, Kate, Nian Zhen, Rose) once their baby was born, while others hoped to continue with the changes to their diet in the future.

On receiving her diagnosis, Juliana, a 41-year-old woman who described difficulty in conceiving, recalled feeling as though she "had to do something quick" to get her blood glucose levels under control immediately, "from that day I decided not to have more umm, treats and cakes and pastries". She felt the timing of her OGTT and the period in which she had to wait for a clinic appointment or advice "took too long". She reported feeling "scared" during the weeks she waited for a GDM clinic appointment and worried about how it was affecting her pregnancy.

Women frequently described sticking to a timetable or "routine" (Rosa) in terms of when they ate and when they tested their blood glucose levels as a way in which they managed having GDM. However, some found this need for regularity difficult to fit in with their existing lifestyles. Huain described finding it "difficult" to have her meals "at the same times every day." Similarly, Mai reported being told to "have three main meals a day and snacks between the meals" but found this challenging to fit into her daily routine and "to keep enough time gap between the meal and snacks so that it doesn't impact the readings."

Although initially managing GDM through diet was described as a steep learning curve for many women, on the whole, women reported they "get used to it" (Amipa, Deepti, Gretchen, Marama, Moeroa) and gain confidence and competence over time. Many reported that only needing to follow recommendations for the duration of their pregnancy made it easier to comply with the restrictions placed on their diet. Juliana said "at least I hope, there's a deadline. I know that it's going to end. So, it's easier to manage." Similarly for Kate, watching those around her consume foods and drinks she was trying to avoid was made easier because "I've just got a few more weeks of this" conversely she stated, "if it was the rest of my life, I'd probably be a bit more like, how 'bout you drink that while I'm not watching."

The understanding that their actions in the short-term, during pregnancy, could have long-lasting effects on their baby was also a strong motivator for women. Nian Zhen commented, "if you don't behave now, it will be bad impact for the [baby]. So, I don't want that happen. I just suffer 10 months, that will be like the forever years for the [baby]." Similarly, Rachel stated, "if what I'm eating now can affect [the baby], I can cut out sugar, I can cut out white bread, because you know, it could be a lifelong issue for my child if I don't."

A few women described feeling as though they were simply a vehicle for the baby's health and that the healthcare practitioner's primary concern was not for themselves but for the baby. Rose relayed a conversation she had with her midwife demonstrating this:

> "The midwife says you know, if you want to eat this you can eat it after you have the baby, but now, what we're doing here is for your baby."

When healthcare professionals' focus was on the baby, women reporting feeling as though they were "off the hook" or on their own after pregnancy (Rose). Many women talked about relaxing their diet after pregnancy despite their increased risk of developing type 2 diabetes, as their dietary choices would only affect their own health and not that of their baby. However, for some this would be dependent on the *numbers as evidence* that it would be acceptable to do so. Huian stated, "I'll start eating as usual if umm my sugar level is back to normal"

while Nian Zhen planned to continue her dietary restrictions until she "passed" the postnatal blood test, after which she planned to "be crazy naughty again."

Other's took their diagnosis and the advice provided to them as a "wake-up call" (Seini) or "opportunity to reflect" (Fei) on their current lifestyle and make changes to reduce their risk of type 2 diabetes in the future. Moeroa saw her diagnosis of GDM as a learning opportunity not just for her but for her wider family as well:

> "My family they're big eaters as well, just showing them and role modelling like hey there's certain foods we can eat. It's good so that can support them later in the future you know and if they find out they got it [diabetes] then I can just help them out."

Discussion

Findings from this exploratory study have provided an understanding of New Zealand women's experiences of dietary recommendations following a diagnosis of GDM. Overall, participants in this study perceived the primary purpose of dietary advice to be to control their blood glucose levels. Based on the experience of dietary advice, participants managed GDM by balancing the numbers as evidence within their perceived timeframe of consequences from GDM to themselves and their baby.

Whilst some women acknowledged that the prescribed dietary changes equated to a healthier diet, few spoke of receiving dietary advice to ensure a healthy pregnancy or optimise their health; rather, the focus was on maintaining blood glucose levels within limits. One other New Zealand qualitative study exploring barriers and enablers to achieving optimal glucose control in GDM also reported blood glucose results or "numbers" as the focus of women having GDM (Martis, Brown, et al., 2018). Women in that study reported feeling as though their blood glucose results "ran their life" and did not enjoy the shift in focus of their pregnancy to their blood glucose "numbers" (Martis, Brown, et al., 2018). Women in our study reported feeling as though their pregnancy was now "different" because of GDM, consistent with other reports (Evans & O'brien, 2005; Hui, Sevenhuysen, Harvey, & Salamon, 2014; Persson et al., 2010). Indeed, midwives caring for women with GDM have expressed that, once a woman was diagnosed with GDM, her pregnancy was no longer considered normal (Persson, Hörnsten, Winkvist, & Mogren, 2011). These findings may validate women's feelings of having a 'different' or 'medicalised pregnancy' (Evans & O'Brien, 2005; Lawson & Rajaram, 1994), further supported by women reporting that, once they were diagnosed with GDM, their diabetes became the focus of medical attention rather than their pregnancy (Lawson & Rajaram, 1994). In our study, some women described feeling that healthcare professionals had greater concern for the baby than for the women themselves, with the focus on numbers making them feel as though they were merely a vehicle for the baby's health. These findings are consistent with a study in 2018 in which women described feeling that the hospital "claimed ownership of the baby", that

healthcare professionals were now in control of their pregnancy, and that they felt viewed objectively rather than personally and as a "possible obstacle to the baby's wellbeing" (Parsons et al., 2018).

Women with a history of GDM who were in their postpartum period reported feeling abandoned once they had delivered their baby despite their increased risk of type 2 diabetes (Morrison, Lowe, & Collins, 2014; Muhwava, Murphy, Zarowsky, & Levitt, 2020; Parsons et al., 2018; Svensson, Nielsen, & Maindal, 2018). This postpartum abandonment may compound women's feelings of being unimportant and simply "baby machines" and may lead to feelings of ambivalence to their own health (Parsons et al., 2018). A low perception of future risk of type 2 diabetes in a study of 35 women with a history of GDM in South Africa was attributed to the focus on the health of the baby and blood glucose results during pregnancy and subsequent "abandonment" postpartum (Muhwava et al., 2020). We encountered similar feelings with women in our study reporting feeling that after pregnancy they were "off the hook" and could relax dietary restrictions or even "go crazy", as what they ate would no longer affect their baby's health, even though they were aware they would be at risk of type 2 diabetes. We argue that the fetal-centric approach many women described experiencing during pregnancy may negatively impact women's motivation to continue healthy dietary habits that may reduce the risk of type 2 diabetes in the future. Similar findings have been reported in the literature on interventions aimed at smoking cessation during pregnancy (Greaves, Hemsing, Poole, Bialystok, & O'Leary, 2016), in which many women who quit smoking during pregnancy resume smoking within the first year postpartum. Our data indicate that dietary advice received seemed to have the greatest influence on participants' dietary decisions in the short-term. Only a few women reported viewing the information as beneficial for their long-term health or wanting to role model good eating habits for their families. Other studies report that although following a healthy diet and lifestyle was a concern for the whole family during pregnancy, other priorities took over once the baby was born (Muhwava, Murphy, Zarowsky, & Levitt, 2019; Svensson et al., 2018). However, mothers' dietary habits, attitudes and beliefs about food and nutrition are thought to have a significant influence on their children's dietary behaviours (Brown & Ogden, 2004; Contento et al., 1993; Cutting, Fisher, Grimm-Thomas, & Birch, 1999). These findings indicate that healthcare professionals should consider and highlight the importance of healthy behaviours for both mother and baby, and continuing healthy behaviours established during pregnancy both for the future health of the women themselves and of their infants.

Lack of culturally-tailored dietary advice reported in our study and others may pose a barrier for achieving and continuing with dietary behaviour change (Bandyopadhyay et al., 2011; Kaptein et al., 2015; Parsons et al., 2018; Yee et al., 2016). Women from ethnic minorities often experience higher prevalence of GDM (Berkowitz et al., 1992; Hedderson, Darbinian, et al., 2010) and may face additional challenges in understanding and managing the condition (Bandyopadhyay et al., 2011; Bandyopadhyay, 2021; Borgen et al., 2019; Carolan, Steele, & Margetts, 2010; Carolan et al., 2010). A systematic review of studies involving women with a history of GDM proposed that dietary advice not fitting with a woman's cultural identity may make changes more difficult to sustain long-term

(Dennison, Ward, Griffin, & Usher-Smith, 2019). Healthcare professionals need to acknowledge that food is more than simply energy and nutrients. Food plays an important role socially and culturally and, for many women, GDM significantly reduces the enjoyment, spontaneity, social and cultural aspects of food (Bandyopadhyay, 2021). A woman in the study by Svensson et al. (2018) felt the imposed dietary restrictions took away the "joy of pregnancy" (Svensson et al., 2018), a sentiment echoed by several women in our study and in others (Ge, Wikby, & Rask, 2017; Hui et al., 2014). Women described experimenting or "cheating" with different foods as a way of teaching themselves which foods could fit into their GDM 'diet' or as a way to retain some pleasure in their diet. However, for many it was clear that in the initial phases of experimenting, there were a number of blood glucose levels above recommended limits. Women described these as acceptable as they were used to increase the variety of their diet or satisfy their cravings, but few recognised the impact these excursions may be having on their baby. Similar behaviours are commonly described in the literature (Bandyopadhyay et al., 2011; Draffin et al., 2016; Evans & O'brien, 2005; Lawson & Rajaram, 1994). Rather than an act of non-compliance, women described this as a way of minimising the intrusiveness of GDM on their lives (Lawson & Rajaram, 1994). Perhaps if women felt better supported with the dietary adaptations through more individually tailored advice, the need to experiment or "cheat" would be reduced.

A key mediator of women's perceptions of dietary advice in our study was their relationship with the healthcare professional. Being treated with empathy and regular contact or follow-up with healthcare professionals had a positive effect on a woman's relationship with healthcare professionals. When women felt healthcare providers lacked empathy or did not consider their individual circumstances, women implicitly and explicitly reported feelings of mistrust towards healthcare professionals and sought information from alternative sources. Other studies report similar findings (Ge et al., 2017; Hui et al., 2014; Parsons et al., 2018) and that feelings of connection between women and healthcare providers positively influence women's perception of the quality of care and their adherence to treatment (Muhwava et al., 2019). Midwives in Sweden have reported employing a range of different strategies to manage their encounters with women. When unsuccessful in establishing an empowering relationship, wherein they work in partnership with women to manage their GDM, some midwives resort to a paternalistic approach as they feel they have a duty to protect the baby's health (Persson et al., 2011). However, this paternalistic approach has potential to lead to paradoxical results. Reactance theory proposes that interventions that pose a perceived threat to a patient's freedom can lead to non-compliance with recommendations (Fogarty, 1997). This may explain the behaviours of some of the women in our study and others' such as 'cheating' or seeking alternative sources of information (Hui et al., 2014; Parsons et al., 2018). Women's relationships with healthcare professionals during pregnancy has also been reported to influence their engagement with postpartum follow-up and health behaviours after pregnancy (Parsons et al., 2019; Reid et al., 2018). The way in which healthcare professionals interact with women with GDM, rather than just the provision of dietary recommendations, can therefore play a significant role in the women's management of GDM and long-term health outcomes. Greater recognition of the psychological and long-term health needs of women with

complications during pregnancy have led to calls for a more comprehensive, woman-centred life-course approach to maternal health (Filippi, Chou, Barreix, Say, & on behalf of the WHO Maternal Morbidity Working Group (MMWG), 2018; Knaul et al., 2016).

Strengths and limitations

A major strength of this study is the diversity of participants. Participants came from a range of ethnic and social backgrounds and represented a wide range of views and experiences. Open-ended questions were used to capture women's experiences in their own words. Whilst interview questions focused on dietary recommendations, participants were free to share anything relating to their experience at the end of the interview. Recall bias was minimised by conducting the interviews whilst the women were still pregnant. Respondent burden and self-selection bias were reduced by offering women the choice to be interviewed in person, in their own home or at a location close to their GDM clinic site, or over telephone. Whilst some may suggest there is potential for differences in results obtained over the telephone compared to in-person (Opdenakker, 2006) others have found this not to be the case (Sturges & Hanrahan, 2004; Ward, Gott, & Hoare, 2015) and allowing participants to choose their preferred mode of interview may have minimised any effect. As with studies similar to ours, the generalisability of findings may be limited. Participants were recruited from two sites in Auckland, New Zealand, included only women who could converse in English and who were diagnosed before 30 weeks' gestation. Our findings may therefore not be representative of all women diagnosed with GDM in New Zealand or be applicable to other countries where the model of care and experiences of women may be different. However, a systematic review of the psychosocial experiences of women with a diagnosis of GDM found common experiences among a diverse range of women from different countries (Craig, Sims, Glasziou, & Thomas, 2020) and our findings are consistent with those of studies including women from other populations. Our findings are valuable in providing insight into women's experiences of dietary recommendations for GDM and may offer opportunities to adapt the way in which healthcare professionals interact with women with GDM in order to improve their experience and outcomes.

Conclusions

On receiving a diagnosis of GDM, women are faced with a new challenge in navigating through their pregnancy to ensure the delivery of a healthy baby. The dietary advice women received to manage their GDM was primarily perceived as a means to control their blood glucose results for the sake of the baby. The women's relationships with healthcare providers had a significant impact on whether women viewed recommendations positively or negatively. The value of an empathetic healthcare professional who recognises the significant impact GDM can have on a woman's lifestyle, wellbeing and sense of autonomy was demonstrated in the narratives of women in this study. Individually-tailored, culturally appropriate advice and a greater emphasis on the woman with GDM, rather than just "the numbers", is needed. Healthcare professionals should facilitate the establishment of

healthy dietary habits not just for the duration of pregnancy but for the long-term health of both mother and baby. Further research on the experience and attitudes of healthcare professionals caring for women with a diagnosis of GDM could be useful in informing strategies to optimise the healthcare provider-patient relationship and provision of care for women with GDM.

Chapter 6

Discussion

Preamble

That diet plays a critical role in the management of GDM is undisputed. However, what dietary advice should be provided and how this should be delivered has been, and remains, under extensive investigation. Research in GDM has been shrouded by issues of considerable heterogeneity making it difficult to draw clear conclusions from the extensive number of studies in this area. Variation in diagnostic criteria and methods of identifying women with GDM have made it difficult to determine the effect of interventions on meaningful perinatal and long-term outcomes. Trials assessing different types of diet in the management of GDM have been limited by small sample size and heterogeneity leading to a lack of strong evidence from which to make dietary recommendations for women with GDM. Internationally, surveys of dietetic practice show inconsistency in the services delivered and recommendations provided by dietitians (Farhanah et al., 2014; Morrison et al., 2011) leaving women with GDM confused, frustrated and dissatisfied with the advice they receive (Bandyopadhyay et al., 2011; Carolan et al., 2012; Carolan-Olah et al., 2017; Draffin et al., 2016; Neufeld, 2011). Within New Zealand, there is limited research describing the prevalence of GDM, how it is managed and the experience of GDM from women's perspectives. The research conducted and reported in this thesis investigates the dietary management of GDM in New Zealand through four perspectives; 1) an estimation of the prevalence of GDM in New Zealand, 2) comparisons of adherence to dietary recommendations and dietary patterns between pregnant women with and without GDM, 3) a description of the dietetic services and dietary advice provided to women with GDM and 4) an account of the experiences of women with GDM in managing their condition through diet. A summary of the research objectives, findings and implications of this body of work is presented in Figure 7.

Determining GDM prevalence

Analysis of data from a large cohort of pregnant women participating in the GUiNZ study demonstrated that the prevalence of GDM varies significantly according to the source of data used (Lawrence et al., 2019). Self-reported data, hospital coding data and population health datasets as used in this study are commonly used in publications reporting on GDM prevalence internationally. However, many estimates in the literature are based on only one source of data. Our findings showed single source estimates could be up to 13% higher or 39% lower than when data sources were combined to give a best estimate of GDM prevalence. Even when the same types of data were used, significant variation in prevalence could be seen if this came from different sources. For example, both the Ministry of Health and district health boards provided coding data on diabetes status, yet GDM prevalence was almost double in the district health board data when compared to Ministry of Health data. This suggests that prevalence rates of GDM reported in the literature, particularly if only one source of data is used, are likely inaccurate. Others comparing prevalence of GDM according to different sources have shown similar results (Bell et al., 2008; Zheng et al., 2016). These findings highlight the importance of considering the limitations of the data source used in determining GDM prevalence and suggest using more than one data source may give a more accurate reflection of the true prevalence in a population.

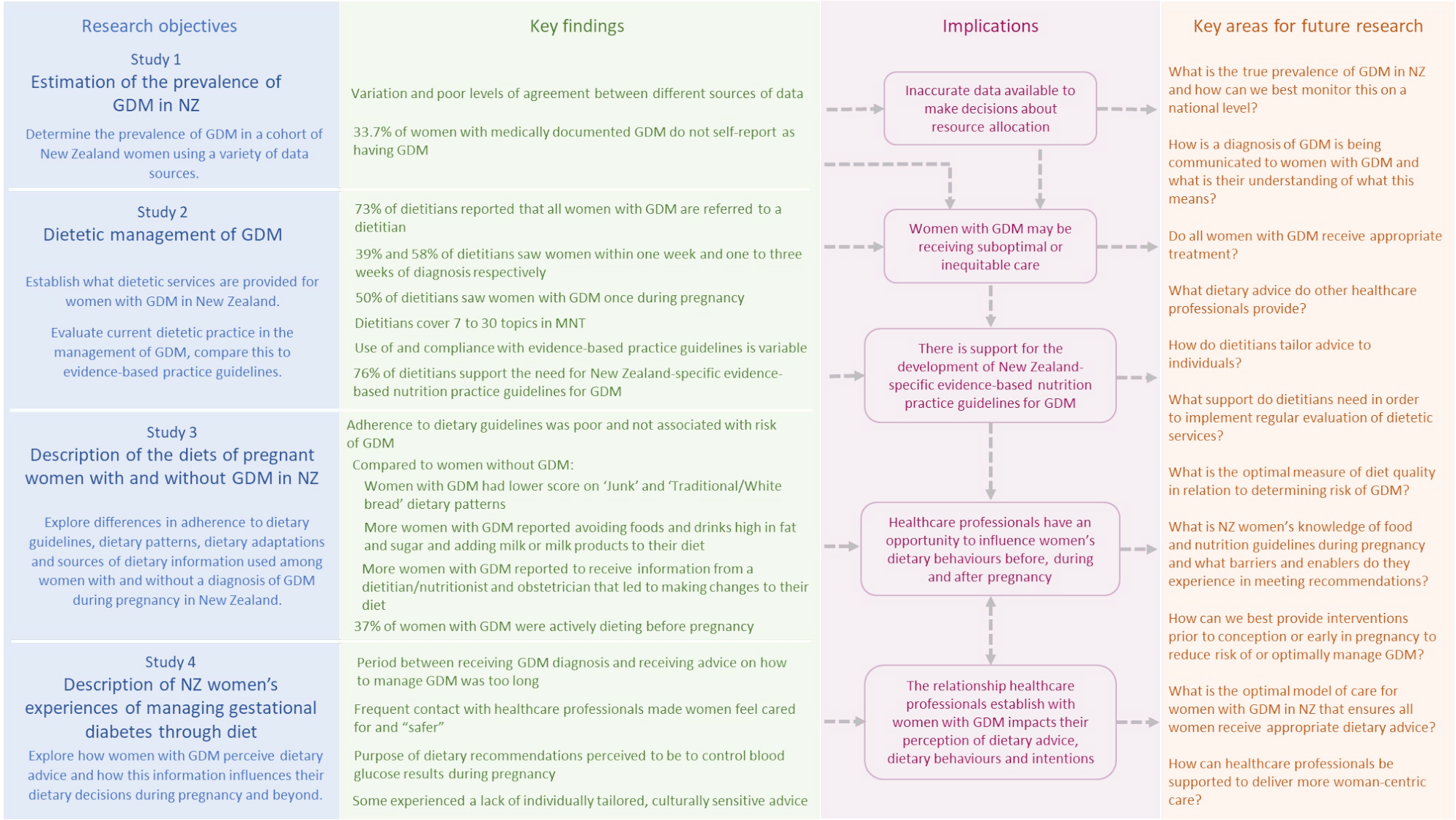

Figure 7. Summary of research objectives, key findings, implications and key research questions

One of the areas of greatest discrepancy in GDM prevalence was prevalence according to self-report and medical data. A third of women with medically-documented GDM reported having no form of diabetes during pregnancy. Whilst it is possible that some of these women had not yet been informed of their diagnosis, when including only self-reported data collected 16-months post-partum there was still a significant proportion of women with medically-documented GDM who denied having diabetes during pregnancy. This questions the validity of using self-reported data in determining prevalence of GDM and presents serious concerns regarding the communication of diagnostic results to women, their understanding of a diagnosis of GDM and whether these women receive appropriate treatment. In a study using grounded theory to explore the process of a diabetes-related diagnosis in 28 individuals, Ledford et al. (2021) reported multiple cases where patients described not hearing, understanding, or accepting instructions from clinicians despite the clinician documenting patient understanding (Ledford, Seehusen, & Crawford, 2021). In the same study, patients felt a diagnosis should be accompanied by the clinician taking action; for example, prescribing medication, issuing a glucometer or referring the patient to education classes, or by the clinician describing negative consequences of the disease such as requiring insulin or developing comorbidities. Patients felt uncertain if the clinician was truly communicating a diagnosis of diabetes if medication was not prescribed or a glucometer was not issued (Ledford et al., 2021). Conflicting messages, the term 'prediabetes' or ambiguous language were also described as barriers to understanding diagnoses (Ledford et al., 2021). Consistent with these findings, others have reported that when GDM was easily managed women tended to question their diagnosis (Morrison et al., 2014). A lack of physical symptoms for GDM and the delivery of seemingly healthy infants contributed to women's perception that GDM was not a severe illness or a disbelief in their diagnosis of GDM (Ge, Wikby, & Rask, 2016a). Similarly, in a study of 13 women with a history of GDM, women reported that clinicians used language that was too technical, did not check their understanding of the diagnosis, and did not provide verbal or written information about GDM at the time of diagnosis (Kilgour, Bogossian, Callaway, & Gallois, 2015). In the same study, some women described that the birth of the baby signalled the end of GDM for them and that a lack of discussion around GDM and postnatal screening after the birth of baby indicated that their diagnosis of GDM was not important (Kilgour et al., 2015). Based on these findings, it may be that women with GDM in the GUiNZ study who did not require medication for the management of GDM, who were asymptomatic, or those who were not encouraged to complete postanal screening for diabetes, did not consider themselves as having GDM in pregnancy. Whether or not the communication they received was pitched at the appropriate level to facilitate understanding of the diagnosis is an additional factor. Further research exploring the communication of a diagnosis of GDM and women's understanding of this is important to address these findings in New Zealand.

Accurate estimation and projections of GDM prevalence are critical for service planning and resource allocation. Findings from our survey of dietetic practice and others (Meloncelli et al., 2020; Morrison et al., 2011) report limited availability of resources as a barrier to providing dietetic services for women with GDM. This suggests that the figures currently used for service planning and resource allocation are inadequate. There is a clear need for greater uniformity and accuracy in GDM prevalence reporting, not just in New Zealand but globally. Along

with the limitations in different data sources described above and in Chapter 2, differences in screening practices and diagnostic criteria in use internationally further compound the issue. With so many factors influencing the determination of the presence and prevalence of GDM in a population, comparison of research findings is difficult even before other differences in research methodology are considered, making it difficult to draw meaningful conclusions. If any progress is to be made in answering the many questions surrounding GDM prevention and management, greater accuracy and consistency in the diagnosis and determination of the true prevalence of GDM is urgently needed.

Adherence to dietary recommendations and dietary patterns among women with GDM

Internationally and in New Zealand, studies have shown a large proportion of pregnant women do not meet food and nutrition recommendations (Malek, Umberger, Makrides, & Zhou, 2016; Morton et al., 2014; Saunders et al., 2019). Data from our analyses show that the same is true of women with GDM in New Zealand and are consistent with findings from the only other study of adherence to dietary recommendations among women with GDM in New Zealand (Mustafa et al., 2021). Only 3.2% of women with GDM met the recommended number of servings for all food groups and over a quarter met none of the recommendations. There were no significant differences in the proportion of women meeting any number of food group serving recommendations between women with or without GDM and meeting recommendations was not associated with odds of developing GDM. This is consistent with findings from other studies using similar measures of diet quality (Gicevic et al., 2018; Gresham et al., 2016), while those using more detailed measures of diet quality have shown a higher diet quality to be associated with a lower risk of developing GDM (Ding et al., 2021; Gicevic et al., 2018). It may be that simply meeting the number of servings recommended for each food group is not enough to reduce a woman's risk of GDM or that adherence to food group serving recommendations is not a sensitive enough measure of diet quality to detect differences in risk of GDM.

Our comparisons of dietary patterns and dietary adaptations between women with and without a diagnosis of GDM was the first to describe the dietary patterns of women with GDM in New Zealand. We found women with GDM had lower mean scores on 'Junk' and 'Traditional/White bread' dietary patterns and higher mean scores on the 'Fusion/Protein' dietary pattern. After controlling for confounding factors, a higher score on the 'Junk' and 'Traditional/White bread' was associated with lower odds of having a diagnosis of GDM. This is in contrast to the literature exploring associations between dietary patterns and risk of GDM (Donazar-Ezcurra et al., 2017; Schoenaker et al., 2015; Sedaghat et al., 2017; Shin et al., 2015; Zareei et al., 2018; Zhang, Schulze, et al., 2006). However, results of stratified analyses indicated that overall findings could be explained by a treatment effect. Around three quarters of women reported receiving information from a midwife that led to changes to their diet. Significantly more women with GDM reported receiving information from dietitians or nutritionists and obstetricians and more women with GDM reported avoiding foods and drinks high in fat and sugar and adding

milk and milk products to their diet. This likely reflects the care they received as part of their management of GDM and is consistent with the recommendations dietitians reported making in the survey of dietetic practice (Chapter 4). These findings highlight the role healthcare professionals play in influencing women's dietary decisions. Midwives are a commonly reported source of information leading to dietary adaptations during pregnancy (Brown et al., 2020). Surveys of New Zealand midwives have reported only 37% received formal nutrition education (Elias & Green, 2007), yet all midwives reported providing nutrition advice but also expressed a desire for greater support in doing so (Pan et al., 2014). Similar findings are reported internationally, in which midwives have expressed positive attitudes towards their role in educating women about nutrition but experience a lack of training and confidence in this area (Arrish et al., 2016; Wennberg, Hörnsten, & Hamberg, 2015). In the survey by Pan et al. (2014), just over half of New Zealand midwives reported being aware of guidelines for optimal weight gain in pregnancy. Similar questions around nutrition recommendations were not included in the survey; therefore, midwives' familiarity with food and nutrition guidelines during pregnancy in New Zealand is unknown.

Over a third of women with GDM compared to a quarter of women without GDM in the GUiNZ study reported actively dieting before pregnancy. This, together with findings from our qualitative study of women's perception of dietary advice for GDM (Chapter 5) and reports in the literature (Hjelm et al., 2008; Hjelm et al., 2007; Parsons et al., 2018; Razee et al., 2010; Wah et al., 2019), suggests women are receptive to dietary advice to improve pregnancy outcomes or interventions delivered in early pregnancy or even pre-conceptionally to mitigate their risk of GDM. Despite numerous interventions initiated during pregnancy, few have shown benefit in reducing risk of GDM in later pregnancy (Griffith et al., 2020). This suggests perhaps the greatest opportunities for the prevention of GDM, or for instilling behaviours that may result in better management of GDM, lie in the pre-conception or periconceptional period. How this might be achieved requires further investigation. A recent report by the New Zealand Institute of Economic Research identified an urgent need for the creation of dietetic positions in primary care, with one potential role being interventions to improve pregnancy outcomes (Hogan & Tuaño, 2021). General practitioners or midwives are well-placed to provide basic lifestyle advice (Bahri Khomami et al., 2021) or to refer women to dietitians for dietary advice to support a healthy pregnancy. Whilst this may be achievable for planned pregnancies, the large proportion of unplanned pregnancies (Morton et al., 2013) presents a significant missed opportunity for preconception care. There have been calls for the provision of systematic advice and support for all women of childbearing age to achieve a healthy weight and lifestyle in order to optimize health outcomes for mothers, children and future generations (Hanson et al., 2015; Miller et al., 2014). This requires a shift in policy with greater focus on preventative healthcare and investment in better public health interventions to improve diet and lifestyle education and support for all women of childbearing age.

Dietetic management of GDM

The survey of dietetic practice in the management of GDM was the first to describe what dietetic services are provided, what advice dietitians give to women with GDM and what dietitians use to inform and evaluate their practice in managing GDM in New Zealand. The survey results were comparable to surveys conducted in Australia and Malaysia (Farhanah et al., 2014; Morrison et al., 2011). Findings revealed that not all women with GDM are receiving support from a dietitian despite evidence showing that this is beneficial (Garduño-Alanis et al., 2020; Reader et al., 2006; Shushan et al., 1997). With over a third of dietitians reporting that dietetic staffing levels influence the frequency of visits with a dietitian, inadequate dietetic resource may be one reason why some women with GDM are not being seen by a dietitian. Another may be that the benefits of dietetic input are not fully appreciated by other members of the multidisciplinary team (Meloncelli et al., 2019; Wilkinson et al., 2014) or that referral to a dietitian is not embedded in GDM service protocols. Dietitians reported variation in the services and advice provided, with few reporting their dietetic service for women with GDM was evaluated. Similar results were reported in a recent survey of dietetic services within maternity care across Australia, in which few sites monitored service effectiveness and only one delivered care for women with GDM according to nutrition practice guidelines (Wilkinson, Donaldson, & Willcox, 2020). Further findings revealed low dietetic staffing levels, lack of processes to deliver and evaluate services and concerns around capacity to deliver evidence-based care. The authors stressed the need for operative dietetic service delivery models which incorporate not only evidence-based MNT but also processes for monitoring the effectiveness of dietetic input (Wilkinson et al., 2020). Without evaluation, there is a missed opportunity to generate evidence to support the impact of dietetic input in GDM and areas needing improvement are more likely to be overlooked. There was strong support from dietitians for the development of New Zealand-specific evidence-based nutrition practice guidelines for GDM with specific areas of focus identified (Lawrence et al., 2016). An evidence-based practice guideline could improve provision of dietetic services offered to women with GDM through establishment of a model of best practice and provide a framework from which to base requirements for dietetic resources and a benchmark for service evaluation (Wilkinson et al., 2020).

Women's experience of managing GDM and perceptions of dietary advice

Our description of women's experiences of dietary management of GDM from their perspective gives voice to women in New Zealand experiencing GDM and adds to the limited literature describing women's experiences of managing GDM in New Zealand. Our study is the first in New Zealand to specifically focus on dietary management of GDM. It provides new insight into how women perceive dietary advice to manage GDM and how this influences their dietary decisions during pregnancy and dietary intentions after pregnancy. Women perceived the overriding purpose of dietary advice to be to keep their blood glucose results within range. Women expressed a desire for more individually tailored, culturally relevant advice, a sentiment echoed in much of the literature in this area (Bandyopadhyay et al., 2011; Bandyopadhyay, 2021; Draffin et al., 2016; Kaptein et al.,

2015; Yee et al., 2016). Findings from the GUiNZ study, in which differences in adherence to food and nutrition recommendations were seen according to ethnicity (Morton et al., 2014), and longstanding disparities in health outcomes particularly for Māori and Pacific people with diabetes in New Zealand (Yu et al., 2021), further demonstrate the need for culturally appropriate interventions.

Our research also brings to light the impact women's relationships with healthcare professionals can have on their perception of advice and care received. Women reported positive, trusting relationships with healthcare professionals when they felt listened to, or when their individual circumstances were taken into consideration. Conversely women spoke negatively and described a lack of trust in healthcare professionals when they were not treated as an individual or when the advice provided was not adapted to their personal circumstances. Similar findings are described in a study involving 13 women with a history of GDM in which communication accommodation theory was used to explore and assess women's communication experiences of GDM postnatal follow-up. They found when women's communication needs were met, women viewed clinical interaction positively; conversely, when communication needs were not met, women viewed the experience or the clinician negatively (Kilgour et al., 2015). Trusting relationships with the healthcare professionals have been shown to be a predictor of treatment adherence, patient satisfaction (Thom, Ribisl, Stewart, & Luke, 1999) and lower HbA1c levels in people with diabetes (Lee & Lin, 2011). A number of factors have been shown to contribute to a trusting relationship between patient and healthcare professional including: perceived competence of the healthcare processional; patient-centred care; empathy; communication, and shared decision-making (Croker et al., 2013; Fiscella et al., 2004; Jacobs, Rolle, Ferrans, Whitaker, & Warnecke, 2006; Street, Makoul, Arora, & Epstein, 2009). Conversely, a critical discourse analysis of New Zealand government, Australasian public media and international academic literature found that the literature describes women as singularly responsible for achieving adequate nutrition during pregnancy, and that fear and monitoring are used to encourage compliance to complex food guidelines (Raven & Stewart-Withers, 2019). Women in our study were more receptive to empathetic, collaborative care in which they were involved in decision-making and when healthcare professionals showed an appreciation for the impact GDM has on their lifestyle, wellbeing and sense of autonomy.

A women's experiences during pregnancy can have a lasting effect on their health behaviours postnatally (Parsons et al., 2019; Parsons et al., 2018). A number of women in our study viewed the need to make changes to their diet as temporary and planned to relax their diet after pregnancy, when it would no longer have an impact on their baby's health. This, together with other aspects of women's shared experiences, corroborate themes of reproductive ascetism and women as 'baby machines' described in the literature (Parsons et al., 2018). A fetal-centric approach in managing GDM and focus on blood glucose results is thought to contribute to a low perception of future risk of type 2 diabetes in some women (Muhwava et al., 2020) and may explain women's intentions to relax their diet postnatally. Others have described the strict regulation of dietary behaviours

imposed by GDM during pregnancy lead to rebellious dietary behaviours after the birth of the baby (Parsons et al., 2019). A finding similar to the intentions expressed by some women in our study. Meta-analysis of qualitative studies exploring women's views of postnatal screening for type 2 diabetes described a woman's relationship with healthcare professionals and understanding of GDM and postnatal risk of type 2 diabetes to influence screening rates (Dennison, Fox, Ward, Griffin, & Usher-Smith, 2020). Just over half of dietitians in our survey of dietetic practice reported discussing postnatal diet during their consultations with women with GDM (Lawrence et al., 2016). Based on these findings, discussions around postnatal diet and risk of type 2 diabetes warrants greater attention during pregnancy. Our findings call for a more woman-centred approach to the management of GDM. A woman-centred, holistic approach that involves women in finding ways to achieve a healthful diet that fits within her cultural and social values is likely to have a greater impact on women's dietary behaviours and has potential to lead to long-term health benefits for both women and their families (Brown & Ogden, 2004; Raven & Stewart-Withers, 2019; Scaglioni, Salvioni, & Galimberti, 2008).

Strengths and limitations

The strengths and limitations of the research conducted as part of this thesis are described in the chapters of each individual study. A key strength of this body of work as a whole is the holistic view this research provides in describing the dietary management of GDM in New Zealand and the triangulation of findings from different research studies. Each research project describes a different aspect of dietary management of GDM, utilizing data from a variety of sources, and places women with GDM as the central focus as illustrated in Figure 8. A limitation the survey of dietetic practice is that it is difficult to ascertain how advice might be tailored to each individual woman through the nature of the survey questions. Instead, the results of the survey give a broad overview of what advice might be covered during consultations. It is unclear from the survey whether there are differences in the advice provided in group education sessions compared to individual appointments. It would also have been helpful to widen the survey to include other healthcare professionals providing dietary advice to women with GDM, such as midwives and diabetes nurses, in order to gain a greater understanding of what dietary advice is provided to women with GDM.

The research studies exploring GDM prevalence and dietary patterns and adherence to food and nutrition recommendations used data from the GUiNZ study which are now more than 10 years old. Given growing trends in obesity and older maternal age (Ferrara, 2007; Lavery et al., 2016; Malik, Willett, & Hu, 2013), the prevalence of GDM in New Zealand is likely to be greater than that reported in Chapter 2. However, as there is currently no national system in place for monitoring and reporting the prevalence of GDM, this is likely to be the most representative estimate of national prevalence available at present. The diets of pregnant women and their adherence to nutrition recommendations may also have changed over the last 10 years and, therefore, the dietary patterns and rates of adherence to recommendations may not reflect current eating habits of pregnant

women in New Zealand. The use of adherence to the number of recommended servings for each of the four food groups is a crude measure of diet quality. This method does not consider other aspects of the diet such as intake of discretionary or less healthy foods which may contribute to the risk of developing GDM. A more detailed measure of diet quality, such as the Alternate Health Eating Index-2010 (aHEI-2010) (Chiuve et al., 2012) and the Prime Diet Quality Score (PDQS) (Fung, Isanaka, Hu, & Willett, 2018) may have yielded different results. The fact that the data collected as part of the GUiNZ study used in the analyses of GDM prevalence and dietary patterns and adherence to recommendations did not specifically provide data on GDM diagnosis was a further limitation in these studies. This was overcome by using NHI linking to collect data on GDM status through clinical coding and laboratory results. However, these data may still be limited by missing data and in the interpretation of laboratory results. The self-reported data on diabetes status during pregnancy was also only a proxy for GDM as both questions in the antenatal interview and in the 16-month interview referred to "diabetes during pregnancy" rather than GDM per se.

Figure 8. Women with GDM at the centre of research contributing to this thesis.

Each outer layer has an impact and influence on the inner layer, thereby all affecting the woman's experience of GDM.

Implications and recommendations for clinical practice

The findings of the research presented in this thesis demonstrate that current estimates of GDM prevalence in New Zealand, which are based on a single data source, are likely to be inaccurate. This limits their usefulness in service planning and resource allocation. With trends of increasing rates of GDM (National Women's Health, 2021; Winnard, Anderson, MacLennan, Okesene-Gafa, 2013), expansion in the capacity of current GDM services are likely to be required. The establishment of a national, unified system of GDM prevalence reporting should be considered and the reform to the New Zealand health system provides an opportunity for this (New Zealand Government, 2021).

Our findings support the development of evidence-based practice guidelines for dietary management of GDM in New Zealand. These should include recommendations on carbohydrate distribution and minimum carbohydrate requirements, macronutrient distribution, special considerations for ethnic groups, guidance on the mode and, frequency of dietetic input during and after pregnancy and recommendations for implementation and evaluation of services. These guidelines should be developed in consultation with dietitians, wider members of the multidisciplinary team and women who have experienced GDM in order to incorporate their views on how to best support women in the management of GDM (Krahn & Naglie, 2008; World Health Organization, 2014). Regular evaluation of dietetic services in the management of GDM should be implemented. Benchmarking current practice against best practice may highlight areas requiring further attention and resources in order to provide optimal care for women with GDM. This is particularly important in the face of the rising rates of GDM.

Healthcare professionals should be supported to provide more woman-centred, culturally sensitive care. Women with GDM are willing to make changes to their diet in order to optimize outcomes for themselves and their babies and recognize the value of making these changes early but many may not appreciate the benefit of continuing with new healthful behaviours after the birth of their baby. Greater attention to informing women of the benefit of continued healthy behaviours postnatally are warranted. Healthcare professionals have an opportunity to influence women's dietary behaviours before, during and after pregnancy if only systems are in place and resources available to do so.

Areas for future research

Further research questions that arise from the findings of the studies included in this thesis are summarized in Figure 7 and listed in further detail below:

Prevalence of GDM in New Zealand

- What is the true prevalence of GDM in New Zealand and how can we best monitor this on a national level?
- How is a diagnosis of GDM communicated to women and what is their understanding of this diagnosis?

Dietary interventions for women with GDM

- Is dietetic intervention associated with better perinatal and postnatal outcomes for women with GDM in New Zealand? Is greater contact with a dietitian associated with better outcomes?
- What happens to the women with GDM who are not referred to a dietitian for advice, who provides them with dietary advice and what are their perinatal outcomes and perceptions and intentions relating to dietary advice?
- What dietary advice do other healthcare professionals provide to women with GDM and how confident and competent are they in doing so?
- How can we provide advice on the management of GDM soon after diagnosis in order to achieve optimal outcomes and minimize the emotional distress that accompanies a diagnosis of GDM?
- What is the optimal model of care for women with GDM in New Zealand that ensures all women with GDM receive appropriate dietary advice to manage their condition?
- How do dietitians tailor advice to individuals? Are there differences in the advice provided in group education sessions compared to individual appointments? Do women have a preference for group or individual dietary education sessions? Are there differences in outcomes for women with GDM who attend only group dietary education sessions compared to those who receive one-on-one advice?
- What support do dietitians need in order to implement regular evaluation of dietetic services?
- How can healthcare professionals be supported to provide more women-centred care?

Diet and lifestyle of women of childbearing age

- How can we best provide interventions prior to conception or early in pregnancy to reduce the risk of women developing GDM or facilitate optimal management?
- What is the optimal measure of diet quality in relation to determining risk of GDM?
- Are there dietary patterns that are associated with an increased or decreased risk of developing GDM in New Zealand women? Assessment of dietary intake should be conducted preconceptionally or in early pregnancy to minimize any affect of treatment on outcomes.
- Is adherence to the newly released Eating and Activity Guidelines (Ministry of Health, 2020b) associated with the risk of developing GDM?
- What are New Zealand women's knowledge of food and nutrition recommendations during pregnancy?

- What barriers and enablers do pregnant women of childbearing age experience in achieving food and nutrition recommendations?
- How familiar are lead maternity carers with food and nutrition recommendations for pregnancy?

Concluding remarks

Availability of dietetic resources is a commonly cited barrier to the provision of care for women with GDM. A system of regular GDM prevalence reporting on a local and national level is urgently needed to provide data for service planning and resource allocation. New Zealand-specific guidelines for the dietary management of GDM is needed to support dietitians and other healthcare professionals to provide consistent, evidence-based care to women with GDM. Evaluation of dietetic services for women with GDM should be incorporated into routine practice in order to generate data on the impact dietitians have in GDM management and identify areas requiring improvement. Women with GDM are receptive to dietary advice to improve the health of themselves and their baby and consider advice from a range of sources. A women's relationships with healthcare professionals have a significant impact on their perceptions of dietary advice. A greater emphasis on individually tailored, culturally appropriate, women-centred care is needed. Our findings suggest that women who go on to develop GDM are making changes to their diet before their diagnosis and a considerable proportion are actively dieting before pregnancy. The findings presented in this thesis highlight the opportunity healthcare professionals have in influencing women's diets before, during and after pregnancy. How we can best provide consistent but individually tailored dietary advice and services to women in a timely manner in order to achieve optimal perinatal and long-term outcomes warrants further investigation.

Appendix 1. Summary of Ministry of Health Food and Nutrition guidelines for pregnant women

Table S1. Number of servings for each food group recommended by the Ministry of Health Food and Nutrition Guidelines for pregnant women and criteria for analyses

Food group	Number of servings recommended per day	Examples of serving size	Specific foods included or excluded from analyses of adherence to food group recommendations
Fruit and vegetables (includes fresh, frozen, canned and dried)	≥ 2 fruit and ≥ 4 vegetables Only one serving of juice or dried fruit counts towards the total number of servings per day	1 medium (135 g) potato or kūmera ½ cup cooked, salad or mixed vegetables 1 apple, pear, banana (130 g) 2 small apricots or plums (100 g) ½ cup fresh, stewed, frozen or canned fruit 1 cup fruit juice 2 tablespoons dried fruit	Hot chips, French fries, wedges or kūmara chips not included† Only 1 serving of juice or 1 serving of dried fruit were counted in the total sum of intake
Breads and cereals (includes breakfast cereals, breads, grains, rice and pasta, preferably wholegrain)	≥ 6	1 bread roll (50 g) 1 medium slice of bread (26 g) ½ cup muesli ½ c cooked porridge 1 cup cooked rice or pasta	Cakes and biscuits not included
Milk and milk products (includes milk, cheese, yoghurt and ice-cream and alternatives. Advised to choose low or reduced fat options.)	≥ 3	1 cup of milk 1 pot of yoghurt (150 g) 2 slices of cheese (40 g) 2 scoops of ice-cream	
Lean meat, poultry, seafood, eggs, nuts and seeds and legumes	≥ 2	2 slices cooked meat (100 g) ¾ cup mince or casserole (195 g) 1 egg 2 chicken drumsticks or 1 chicken thigh (110g) ¾ cup cooked dried beans, peas or lentils ½ cup nuts or seeds	Does not include chicken nuggets, chicken roll, processed meats, battered of fried fish, or food prepared in fast-food outlets

†French fries are long thinly cut slices of potato, hot chips are thickly cut slices of potato and kūmara chips are New Zealand native potato fried in fat.

Appendix 2. Survey of dietetic management of gestational diabetes in New Zealand

This survey is intended for dietitians providing nutritional advice to women with Gestational Diabetes Mellitus (GDM). This survey aims to describe current practices in the provision of dietary advice to women with GDM in New Zealand as part of a PhD thesis. This research focuses on GDM first diagnosed in pregnancy, and not on women with known pre-existing type 1 or type 2 diabetes. When completing the survey, please consider your responses in relation to women with GDM and not women with type 1 or type 2 diabetes. The survey takes approximately 20 minutes to complete. Your participation is voluntary, anonymous and is greatly appreciated.

Consent statement

I have read the Participant Information Sheet, and I have understood the nature of the research and why I have been selected. I have had the opportunity to ask questions and have them answered to my satisfaction.

- I agree to take part in this research.
- My participation is voluntary.
- I understand that my responses will be kept for a minimum of 6 years after which time they will be destroyed.
- I understand that my responses may be used to form part of a PhD thesis and may be published in forms other than part of a PhD thesis, such as journal articles or conference presentations.
- I understand that my responses are anonymous and all efforts will be taken to protect my anonymity and therefore it is not possible to withdraw my responses after submitting the survey.
- I understand that if I wish to receive a summary of findings, I will contact Robyn Lawrence via r.coetzee@auckland.ac.nz to request a copy of these results.

Researcher contact details:

Robyn Lawrence	Professor Caroline Crowther	Professor Frank Bloomfield
PhD Student	Primary supervisor	Director
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09 9236691	09 373 7599 ext 86011	09 923 6107

Approved by the University of Auckland Human Participants Ethics Committee on 09/08/2015 for three years. Reference number 015347.

I consent to participate in this survey:

- Yes
- No

DEMOGRAPHICS

1. Within which region do you currently practice? (select one)

   - Upper North Island (Northland, Auckland, Waikato, Bay of Plenty, Gisborne regions)
   - Lower North Island (Taranaki, Manawatu, Wanganui, Hawke's Bay, Wellington regions)
   - South Island
   - Locum / Multiple locations
   - Other – please specify _____

2. How would you describe your work geographic location? (select all that apply)
   - Metropolitan / urban (population >100,000)
   - Regional
   - Rural / Remote
   - Other – please specify _____

3. In what setting do you currently work? (select all that apply)
   - Public Hospital
   - Specialised Diabetes Service
   - Community Health Centre
   - Private Practice
   - Private Hospital
   - Non-government organisation
   - Other – please specify _____

4. What is your primary area of practice? (select one)
   - Diabetes
   - Antenatal / Obstetrics
   - General Clinical
   - Community nutrition
   - Other – please specify _____

5. What is your current employment status? (select one)

- Full-time
- Part-time
- Consultancy / Contract
- Other – please specify _____

6. From which institution did you gain your Dietetics qualification? (select one)
   - University of Auckland
   - University of Otago
   - Massey University
   - Other – please specify _____

7. Have you ever practised dietetics in a country other than New Zealand?
   - Yes
   - No

   Comment: _____

8. Do you have a current annual practising certificate from the Dietitians Board of New Zealand?
   - Yes
   - No

9. How many years in total have you worked as a dietitian?

_____

10. How many years have you been working in gestational diabetes?

_____

11. Are you a current member of Dietitians New Zealand?
    - Yes
    - No

12. Are you a member of the Dietitians New Zealand Diabetes in Pregnancy Specialist Interest Group?
    - Yes
    - No

13. How many women on average would you see with GDM each month?

    _____

14. Does the service within which you see women with GDM include other members of a multidisciplinary team?
    - Yes
    - No

14 i) If yes, please indicate which team members: (select all that apply)

- Endocrinologist / Diabetes specialist doctor
- Obstetrician
- Maternal fetal medicine sub specialist
- Midwife
- Diabetes specialist midwife
- Diabetes specialist nurse
- Psychologist
- Physiotherapist
- Language interpreting service
- Other – please specify _____

14 ii) If no, do your clients with GDM have access to other members of the multidisciplinary team through another service?

- Yes
- No
- Unsure

Comment: _____

15. Are all women with GDM who attend your service (or sent by a referring lead maternity carer) referred to see a dietitian?
    - Yes
    - No
    - Unsure

Comment: _____

15 i) If no, under what circumstance are women with GDM usually referred for dietetic advice? (select all that apply)

- Commencement of oral diabetes medication
- Commencement of insulin
- Poor glycaemic control
- Weight-related issues
- Pregnancy-related issues (e.g. nausea, heartburn, poor appetite)
- Other – please specify _____

16. Are all women who are referred to see a dietitian seen by a dietitian?
    - Yes
    - No
    - Unsure

Comment: _____

17. How soon after referral are women with GDM usually seen by a dietitian? (select one)
    - <1 week
    - 1 to <3 weeks
    - 3 to <4 weeks
    - >4 weeks

18. What type of dietetic services do you provide for women with GDM? (select all that apply)
    - Individual appointments
    - Group education sessions
    - Telephone
    - Email follow-up
    - Text messaging
    - Other – please specify _____

19. Are women with GDM provided with any initial nutrition information (e.g. written information, meal plan) prior to their first dietetic appointment?
    - Yes
    - No
    - Unsure

    Comment: _____

19 i) What topics does this information cover? (Select all that apply)

- Core food group requirements
- Sources of carbohydrate, protein and fat
- Carbohydrate quantity
- Carbohydrate distribution
- Simple sugars
- Glycaemic index
- Fat
- Saturated fat
- Fibre
- Free foods
- Artificial sweeteners
- Alcohol
- Folic acid
- Vitamin D
- Calcium
- Iodine
- Iron
- Caffeine
- Label reading
- Eating out and takeaways
- Hypoglycaemia
- Physical activity
- Pregnancy weight gain
- Food safety to reduce the risk of foodborne illness
- Mercury
- Vitamin A
- Breastfeeding
- Risk reduction of type 2 diabetes
- Postnatal diet
- Other – please specify _____

If you have access to and are willing to provide this information for research purposes it would be greatly appreciated. You can do so by uploading a copy of the information to this anonymous link xxxx.

20. On average, how many face-to-face visits (including individualised appointments and group education) would each woman have with a dietitian during their GDM pregnancy (excluding telephone or email contact)? (select one)
    - None
    - One
    - Two
    - Three
    - Four
    - Five or more

21. On average, how many episodes of indirect contact, such as telephone, text messaging, email or posted information, would each woman have with a dietitian during their GDM pregnancy? (select one)
    - None
    - One
    - Two
    - Three
    - Four
    - Five or more

22. What influences the decision on the frequency of dietitian visits? (select all that apply)
    - Dietetic staffing levels
    - Service protocols or guidelines
    - Glycaemic control
    - Use of insulin or oral diabetes medications
    - Cultural background / language
    - Availability of language interpreter
    - Client literacy levels
    - Dietitian's clinical judgement
    - Schedule of appointments with other multidisciplinary team members
    - Other – please specify _____

23. For each woman with GDM, how much time (in minutes) with a dietitian is allocated for? (If a particular service is not offered, please indicate so by writing NA.)
    - Initial individual assessment and advice _____
    - An individual follow-up appointment _____
    - Group education _____

- Follow-up group education _____
- Telephone, text messaging or email follow-up _____

24. Do you believe that the service within which you see women with GDM, currently offers adequate dietetic services for women with GDM?
    - Yes
    - No
    - Unsure

Comment: _____

DIETETIC EDUCATION AND ADVICE

25. Which of the following topics do you discuss when giving dietary advice to women with GDM? (select all that apply)
    - Core food group requirements
    - Sources of carbohydrate, protein and fat
    - Carbohydrate quantity
    - Carbohydrate distribution
    - Simple sugars
    - Glycaemic index
    - Fat
    - Saturated fat
    - Fibre
    - Free foods
    - Artificial sweeteners
    - Alcohol
    - Folic acid
    - Vitamin D
    - Calcium
    - Iodine
    - Iron
    - Caffeine
    - Label reading
    - Eating out and takeaways
    - Hypoglycaemia

- Physical activity
- Pregnancy weight gain
- Food safety to reduce the risk of foodborne illness
- Mercury
- Vitamin A
- Breastfeeding
- Risk reduction of type 2 diabetes
- Postnatal diet
- Other – please specify _____

26. Do you recommend specific macronutrient targets for women with GDM?
    - Yes
    - No

Comment: _____

26 i) As a percentage of total energy intake, what macronutrient targets do you suggest in your dietetic interventions with women with GDM?

- Carbohydrate _____
- Protein _____
- Fat _____
- Saturated Fat _____

27. Do you recommend specific targets for the number of servings from each of the food groups?
    - Yes
    - No

Comment: _____

27 i) If yes, how many servings do you recommend for:

- Carbohydrate _____
- Protein _____
- Fruit _____
- Vegetables _____
- Dairy or calcium rich foods _____
- Fats and oils _____

28. Do you give qualitative advice on food groups?
    - Yes

- No

Comment: _____

28 i) If yes, what specific qualitative advice do you give regarding:

- Carbohydrate _____
- Protein _____
- Fruit _____
- Vegetables _____
- Dairy or calcium rich foods _____
- Fats and oils _____

29. Do you specify a target for fibre intake?
    - Yes
    - No

Comment: _____

29 i) If yes, how many grams of fibre do you recommend per day?

_____

Comment: _____

30. Do you recommend that women with GDM include a minimum amount of carbohydrate per day?
    - Yes
    - No

Comment: _____

30i) If yes, how many grams of carbohydrate do you recommend per day?

_____

Comment: _____

31. What teaching tools do you use in dietary education for women with GDM? (select all that apply)
    - General information regarding small meals and snacks spread out over the day
    - Plate model

- Prescribed amounts of carbohydrate at meals and snacks
- Flexible amounts of carbohydrate at meals and snacks
- Ministry of Health 'Eating for Healthy Pregnant Women / Ngā Kai Totika mā te Wahine Hapū' booklet
- Guidance on portion sizes
- Printed information sheets or booklets
- Other – please specify _____

32. If you use printed information sheets or booklets, are these available in languages other than English?
    - Yes
    - No
    - Printed information sheets or booklets not used

32 i) If YES, please specify which languages:

_____

33. What advice do you provide to women with GDM regarding the use of artificial / non-nutritive sweeteners? (choose one)
    - Use any sweeteners as desired
    - Avoid saccharin (954) and cyclamate (952) and use other sweeteners as desired
    - Avoid saccharin (954) and cyclamate (952) and use other sweeteners in small amounts only
    - Use any sweeteners in small amounts only
    - Avoid all sweeteners
    - No advice regarding artificial sweeteners provided
    - Other – please specify _____

34. What advice do you provide to women with GDM regarding the glycaemic index (GI)? (select all that apply)
    - Include at least one low GI carbohydrate at each meal
    - Include at least one low GI carbohydrate at each meal and snack
    - All carbohydrate foods should be low GI
    - Avoid high GI foods
    - No advice regarding GI provided
    - Other - please specify _____

35. In your assessment of women with GDM, do you assess glycaemic control?
    - Yes
    - No

Comment: _____

35 i) If yes, what sources do you use to assess glycaemic control? (select all that apply)

- Women's self-report
- Blood glucose monitoring booklet
- Read off or downloaded from glucometer
- Patient notes / Other health professional reports
- Other – please specify _____

36. Do you provide specific advice about weight gain for pregnancy to women with GDM?
    - Yes
    - No

Comment: _____

36 i) If yes, what weight gain targets do you recommend?

_____

37. What sources of information do you use to inform your practice with women with GDM? (select all that apply)
    - Ministry of Health Food and Nutrition Guidelines for Healthy Pregnant and Breastfeeding Women
    - Ministry of Health Screening, Diagnosis and Management of Gestational Diabetes Mellitus in New Zealand: A Clinical Practice Guidelines
    - National Institute of Clinical Excellence (NICE) Guidelines for Diabetes in pregnancy: Management of diabetes and its complications from pre-conception to the postnatal period
    - American Dietetic Association Evidence Based Guidelines for GDM
    - The Auckland Regional Diabetes Dieticians Standard of Care for the Nutritional Management of Gestational Diabetes
    - Other – please specify _____

38. Overall, how confident do you feel providing dietary advice for the management of GDM?
    - Very confident
    - Confident
    - Somewhat confident
    - Not confident

39. Do you feel the need for New Zealand evidence-based nutrition practice guidelines for GDM?
    - Yes
    - No

Comment: _____

39 i) If yes, what specific areas would you like these guidelines to provide guidance on?

_____

40. Do you refer women with GDM to other healthcare practitioners or services for dietary and/or lifestyle advice?
    - Yes
    - No

Comment: _____

40 i) If yes, which other services do you refer to? (select all that apply)
- Diabetes in pregnancy service
- Green prescription
- Physiotherapist
- Dietitians in other specialist areas
- Diabetes specialist nurse
- Diabetes specialist midwife
- Other – please specify _____

ADDITIONAL COMMENTS

41. Do you have any other comments about dietary management for women with GDM in New Zealand? Comment: _____

Thank you for your interest and participation in this survey! Your time and input is greatly appreciated!

Appendix 3. Approval to use Morrison et al. (2013) survey

LIGGINS INSTITUTE
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NEW ZEALAND

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Dr MK Morrison
Australian Diabetes Council
26 Arundel Street
Sydney, NSW 2037
Australia

8th June 2016

Dear Dr Morrison,

I am a doctoral student from the Liggins Institute at The University of Auckland researching the role of diet in the prevention and management of gestational diabetes mellitus under the direction of my primary supervisor Professor Caroline Crowther.

I am writing to request your permission to use the '*Dietetic practice survey*' published as Appendix C in your thesis entitled '*An investigation into the dietary management of gestational diabetes in Australian women and postnatal health and lifestyle behaviours for future diabetes risk reduction*' 2013 as the basis for the development of a similar survey to be used within New Zealand to form part of my PhD thesis. By using your survey as a foundation, I hope to be able to investigate similar issues in New Zealand and draw comparisons between dietary advice given to women with gestational diabetes in Australia, New Zealand and Malaysia, where your survey was similarly used for research of dietetic practice by Farhanah *et al.* in 2014. The submission date for my PhD is 31st January 2018 and I hope to submit my thesis with publication. With your permission, I will acknowledge your survey as the foundation to the development of the survey used for my research within my thesis and relevant manuscripts I submit for publication.

If you agree to the above, I would be grateful if you could indicate so by signing a copy of this letter and returning it to me either via email or fax:
Email: r.coetzee@auckland.ac.nz
Fax: +64 9 373 8763

If you wish to discuss anything further, please do not hesitate to contact me via the details above or on +64 2040573254.

Sincerely,

Robyn Coetzee
Doctoral Candidate

I, Melinda Morrison, agree to the use of the abovementioned survey under the conditions detailed in this letter.

Signature: Date: 17/6/15

Appendix 4. Semi-structured interview guide

Key question	Related prompt question
Can you tell me a little about your pregnancy so far?	
How did becoming pregnant affect what you eat?	
I understand that you've been told you have pregnancy related diabetes – tell me about that.	• What changed when you found out you had diabetes? • What thoughts did you have when you found out you had diabetes?
What has having diabetes meant for how you eat now?	• Tell me what kind of things you've changed since knowing about your diabetes. • What has gone well around choices you've made about food? • Tell me about a time when things have not gone well. • Tell me about a typical mealtime for you / and your whānau. • What thoughts go through your mind when you are preparing food for yourself / your whānau • Tell me how you imagine things will be once baby has arrived.
How have you found out about foods to eat for diabetes?	• What advice were you given? • How do you feel about this advice / what do you think about this advice? • What differences did it make speaking with a dietitian / other health professionals/ reading information online / listening to whānau / friends • What information was most helpful? • What information was least helpful? • What would you change about the way in which you were given this information?
Is there anything else you would like me to know?	

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