Dietetic Input in Women with Gestational Diabetes and Perinatal Outcomes: A Retrospective Cohort Study

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Abstract

Introduction: Gestational Diabetes Mellitus (GDM) is affecting an increasing number of pregnancies in Aotearoa. A multitude of negative perinatal outcomes are associated with GDM, some of which have been shown to improve with treatment. Medical nutrition therapy is commonly referred to as the cornerstone of treatment for GDM, however little evidence exists to identify the optimal number of appointments, or the optimal method of delivery for dietetic care. The aim of this retrospective cohort study was to describe the level of dietetic input received by women diagnosed with GDM at Te Toka Tumai Auckland, and to determine if dietetic input leads to improved outcomes and whether there is an optimal level of input associated with improved perinatal outcomes.

Methods: Three hundred and eighty women who gave birth at Te Toka Tumai Auckland between 1st July 2022 and 31st December, had a diagnosis of GDM and a singleton pregnancy were included in this study. The number and type of dietetic appointments each woman attended during their GDM affected pregnancy was collected, along with data on perinatal outcomes. Logistic regression was used to calculate the odds of each perinatal outcome dependent on dietetic input.

Results: Of the 380 women with GDM during the study period**,** over half saw a dietitian during their pregnancy (58.2%, n=221), the majority of whom (70.1%, n=155) saw a dietitian once, and 9.5% (n=20) saw a dietitian three or more times. Seeing a dietitian during pregnancy was associated with gestational weight gain within recommendations (aOR = 2.0, CI = 1.07, 3.90) and increased use of insulin or metformin (aOR = 3.37, CI = 1.70, 6.85). Seeing a dietitian once compared to those who did not see a dietitian was also associated with gestational weight gain within recommendations (aOR = 2.58, CI = 1.33, 5.15) and increased use of insulin or metformin (aOR = 4.64, CI = 2.14, 10.70). Seeing a dietitian via telehealth compared to individual in-person was associated with reduced odds of gestational weight gain within recommendations (aOR = 0.22, CI = 0.08, 0.58). Seeing a dietitian via group appointment compared to individual in-person was associated with infants born large for gestational age (aOR = 9.01, CI = 1.05, 81.0).

Conclusion: Not all women diagnosed with GDM at Te Toka Tumai Auckland were seen by a dietitian during their pregnancy. Seeing a dietitian during pregnancy likely improves perinatal outcomes for women with GDM, and seeing a dietitian in-person appears to be superior to

telehealth or group appointments. A small sample size of women who attended more than one appointment with a dietitian made it challenging to assess the optimal frequency of dietetic input, thus further research is needed in this area.

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List of abbreviations

ACHOIS	Australian Carbohydrate Intolerance Study in Pregnant Women
AHREC	Auckland Health Research Ethics Committee
aOR	Adjusted Odds Ratio
BGL	Blood Glucose Level
BMI	Body Mass Index
CI	Confidence Interval
COVID-19	Coronavirus Disease 2019
C-section	Caesarean Section
CVD	Cardiovascular Disease
DASH	Dietary Approaches to Stop Hypertension
FBGL	Fasting Blood Glucose Level
FFQ	Food Frequency Questionnaire
GCT	Glucose Challenge Test
GDM	Gestational Diabetes Mellitus
GI	Glycaemic Index
GWG	Gestational Weight Gain
HAPO	Hyperglycaemia and Adverse Pregnancy Outcome
HbA1c	Glycated Haemoglobin
IQR	Interquartile Range
LGA	Large for Gestational Age
MELAA	Middle Eastern, Latin American, African
MNT	Medical Nutrition Therapy
NCP	Nutrition Care Process
NHI	National Health Identifier
NICU	Neonatal Intensive Care Unit
OGTT	Oral Glucose Tolerance Test
OR	Odds Ratio
SGA	Small for Gestational Age
T1DM	Type 1 Diabetes Mellitus
T2DM	Type 2 Diabetes Mellitus

VIF	Variance Inflation Factor

Chapter 1. Introduction

1.1 Introduction to Gestational Diabetes Mellitus (GDM)

1.1.1 Definition of GDM, global prevalence and diagnosis

Gestational Diabetes Mellitus (GDM) is defined as a glucose intolerance resulting in hyperglycaemia of variable severity with onset during pregnancy (Baz et al., 2016) and poses significant health risks to both mother and infant. Globally, GDM has been estimated to affect approximately 14% (Wang, 2022) of pregnancies, however the significant heterogeneity in screening rates, diagnostic criteria and varying ethnicity-dependent prevalence of GDM present significant challenges for determining true prevalence of GDM globally and when making comparisons from difference regions (Nguyen et al., 2020; Wang et al., 2022). Determining the prevalence of GDM in Aotearoa (New Zealand) faces similar difficulties with heterogeneity. In Aotearoa, GDM has been estimated to affect around six percent of pregnancies (Lawrence et al., 2019), however Lawrence et al. found prevalence estimates to vary from 3.8 to 6.9% depending on the data source used (Lawrence et al., 2019). In Tāmaki Makaurau Auckland specifically, the National Women's Health Annual Clinical report (2022) reported that 812 of the 5295 wāhine (13.7%) who gave birth in 2022 at Te Toka Tumai Auckland had a diagnosis of GDM (National Women's Health, 2022).

Despite inconsistencies in the estimation of GDM prevalence, it is clearly increasing globally, and appears to be rising in parallel with obesity rates (Zahid et al., 2022). Data from the NZ National Women's Health Annual Clinical Report 2021 shows a steep rise in GDM in the last 20 years, with greater prevalence with each increase in body mass index (BMI) category (National Women's Health, 2021). At the end of 2014, the NZ Ministry of Health clinical practice guidelines for GDM introduced the suggestion that all pregnant women should undergo HbA1c screening before 20 weeks gestation, with those whose HbA1c is between 41 and 49 mmol/mol being referred for an 2 hour OGTT (Ministry of Health, 2014b). The introduction of broader screening and diagnostic criteria at this time, along with increasing overweight and obesity (Ministry of Health, 2015) may have contributed to the rise in cases

of GDM. Such significant increases in rates of GDM suggest a need for more resources directed towards the prevention and management of the disease and its related outcomes.

Diagnostic criteria for GDM can vary globally and even regionally (Agarwal, 2015), however is typically diagnosed between 24 and 28 weeks' gestation using an Oral Glucose Tolerance Test (OGTT), where fasting blood glucose levels (FBGLs) are measured before the pregnant women ingest a 75g glucose solution, followed by testing blood glucose levels (BGLs) at one 1 hour and 2 hours. The New Zealand guidelines use 5.5 mmol/L as a cut-off for fasting blood glucose, and 9.0 mmol/L at 2 hours following OGTT. In Aotearoa, the Ministry of Health guidelines outlining the screening processes for GDM recommend pregnant women first have their HbA1c levels tested before 20 weeks' gestation. If their HbA1c is between 41-49 mmol/mol, they are then booked for an OGTT. If their HbA1c appears normal, they are offered a 50g Glucose Challenge Test (GCT). If their BGLs exceed 7.8 mmol/mol, the next step is the diagnostic 75g OGTT (Ministry of Health, 2014b).

1.1.2 Pathophysiology of GDM

Much of the evidence thus far on causal mechanisms for GDM have been relatively inconclusive (Shamsad et al., 2023). Typically, the later stages of pregnancy for any women are accompanied by a decrease in insulin sensitivity (Catalano et al., 1999) as a result of local and placental hormones so that glucose in the blood is delivered to the fetus as opposed to taken up by maternal cells (Plows et al., 2018). While diabetes in pregnancy is only classified as GDM if it is first diagnosed in pregnancy, evidence shows that women diagnosed with GDM were much more likely to have 'subclinical' insulin resistance prior to conception (Baz et al., 2016; Catalano, 2014). Insulin resistance is characterised by a reduction the tyrosine phosphorylation in the insulin receptors on glucose transporters (Friedman et al., 1999), decreasing glucose uptake rate in maternal cells, as well as the development of pancreatic β-cell insufficiency. During normal function, pancreatic β-cells sense blood glucose levels and respond accordingly by secreting an appropriate dose of insulin. When cells become insulin resistant, this further exacerbates β-cell insufficiency (Plows et al., 2018). Emerging research has found genetic components associated with the development of GDM, most of which can

be linked to reduced insulin secretion and the further development of T2DM (Lauenborg et al., 2009; Pervjakova et al., 2022; Zhang et al., 2013).

1.1.3 Risk factors for GDM

Sociodemographic risk factors

As previously noted, the rates of GDM are increasing globally, and within Aotearoa. Some of this rise could be attributed to a rise in the risk factors associated with GDM. Major risk factors for developing GDM include pre-pregnancy BMI (Kim et al., 2010; Mahendra et al., 2022), higher average maternal age (G. Li et al., 2020; Y. Li et al., 2020), socio-economic deprivation (Bittner et al., 2023; Collier et al., 2017; Gnanasambanthan et al., 2023; Lawrence et al., 2020), and Asian or South Asian ethnicity (Lawrence et al., 2020; National Women's Health, 2021).

Women with a BMI score that falls within the 'overweight' or 'obese' categories are at significantly higher risk of developing GDM during their pregnancy (Kim et al., 2010), as well as adverse perinatal outcomes related to GDM (Huet et al., 2018; Miao et al., 2017). Raw data from the National Women's Health report shows higher incidence of GDM with increasing BMI (National Women's Health, 2022). A recent Indian study investigating dietary pattern in association with GDM risk found a higher BMI to be the strongest predictor of GDM, more so than dietary intake (Mahendra et al., 2022). It is thought that increased inflammation associated with overweight and obesity, as well as higher levels of adipose tissue, is associated with increased insulin resistance, thus increasing the chance of glucose intolerance in pregnancy (Kahn & Flier, 2000; Martin et al., 2015), however further research is needed on the exact mechanisms of the relationship between BMI and the development of GDM.

Average maternal age in Aotearoa has been steadily increasing for the last 50 years, and birth rates for women over the age of 30 years have been increasing (Statistics New Zealand, 2019). Based on the evidence available, this could be a contributing factor to the increase in GDM rates nationally, with a large recent meta-analysis showing GDM to have a linear relationship with maternal age (Y. Li et al., 2020). This study found that every one-year age increase from 18 years was associated with a 7.9% increase in GDM risk (Y. Li et al., 2020). While more

evidence is needed to determine the mechanisms between advanced maternal age and GDM risk, reductions in insulin sensitivity with age and increased risk of cardiovascular complications are both thought to be contributing factors (Ferranti et al., 2016). Age and BMI also appear to interact to create a stronger combined risk of developing GDM, with Li et al. showing an increase in GDM incidence by BMI within each age category and vice versa (G. Li et al., 2020).

In Aotearoa specifically, higher levels of socio-economic deprivation are associated with incidence of GDM (Lawrence et al., 2020). This finding reflects other studies around the world associating higher deprivation with risk factors for, and incidences of, GDM (Bittner et al., 2023; Collier et al., 2017; Gnanasambanthan et al., 2023). Socioeconomic deprivation has been significantly associated with reduced access to green spaces for physical activity, high BMI (Pearson et al., 2014) and dietary quality (Wilcox et al., 2020), which may serve as mediating factors in the relationship between socioeconomic status and the development of GDM.

Being of South Asian, Asian or Pacific ethnicity appears to place women at higher risk of GDM than Māori or Pākeha (Lawrence et al., 2020; National Women's Health, 2021). Reasons for higher diagnostic rates in these population have not been investigated at length, but theories include higher screening rates due to ethnicity as an established risk factor, higher BMI in these populations, and higher carbohydrate intake (Yuen et al., 2018). This leads to the observation that treatment for GDM (including that from a dietitian), needs to take into account language barriers and cultural dietary patterns (Yuen & Wong, 2015).

Diet and lifestyle risk factors

Evidence form the Nurses' Health Study II demonstrates a relationship between pre-pregnancy dietary patterns and the risk of developing GDM (Tobias et al., 2012; Zhang, Schulze, et al., 2006). The prospective cohort study included 13,110 women who had a singleton pregnancy between 1992 and 1998, 758 of whom were diagnosed with GDM. Food frequency questionnaires (FFQ's) from the study showed that high adherence to a 'Western' dietary pattern compared to low adherence was associated with an increased risk of GDM

(RR=1.63, 95% CI 1.20-2.21, p=0.001) (Zhang, Schulze, et al., 2006). The Western dietary pattern was characterised by high consumption of red meats, processed meat, refined grains, sweets, fries, and pizza. Women whose diets were low in cereal fibre and had a high glycaemic load had double the risk of developing GDM (RR=2.15, 95% CI 1.04-4.29, p=0.02) (Zhang, Liu, et al., 2006). In a smaller case-control study of 388 women (122 with GDM), a similar finding was established, with those who had high scores in the Western dietary pattern having higher odds of a GDM diagnosis (OR=1.68, 95% CI 1.04-2.27) following adjustment for pre-pregnancy weight, gestational age, physical activity levels, family history of diabetes and home ownership status (Sedaghat et al., 2017).

Zareei et al. (2018) identified a similar dietary pattern, with the addition of soft drinks, juice, and high-fat dairy, to be associated with the development of GDM (Zareei et al., 2018). However, the FFQ took place during the index pregnancy rather than pre-pregnancy as in the Nurses' Health Study II. Conversely, Radeskey et al. (2008) did not find dietary factors during early pregnancy to increase the risk of GDM or glucose intolerance, and commented that pre-pregnancy nutritional status may be a more prudent factor in the development of GDM (Radesky et al., 2008).

Analysis of FFQs from the Nurses' Health Study II showed that adherence to the Mediterranean diet, DASH (Dietary Approaches to Stop Hypertension) diet, or Healthy Eating Index lowered GDM risk by 24-46% (Tobias et al., 2012). While each of these dietary patterns have some distinguishable characteristics, they all follow similar principles: increasing fruits, vegetables, nuts, legumes and wholegrains, and moderating red and processed meats, added sugar and alcohol consumption (Tobias et al., 2012). Women with higher quality diets in the Nurses' Health Study II also had significantly lower pre-pregnancy BMI scores and much higher physical activity scores, however both factors were controlled for in the adjusted analysis, indicating an independent relationship between diet quality and GDM risk (Tobias et al., 2012). A major limitation of the Nurses' Health Study II lies in its ability to be applied to the context of Aotearoa, and more specifically Te Toka Tumai Auckland. While the principles of healthy eating are broadly generalisable, the study was undertaken primarily in Caucasian women, and as outlined by the National Women's Health Annual Clinical Report, this is not the primary demographic of women who are being treated for GDM in Tāmaki Makaurau

(National Women's Health, 2022). Nevertheless, studies of diet quality in other populations have also found higher scores on dietary patterns such as the Healthy Eating Index, Mediterranean-style diets or diets high in vegetables and low in red and processed meats to be associated with a reduced risk of GDM (Hassani Zadeh et al., 2020; Mijatovic-Vukas et al., 2018; Tryggvadottir et al., 2016).

Physical activity is known to improve blood glucose levels by causing glucose uptake in the muscles, thus reducing glucose levels in the blood stream (Stanford & Goodyear, 2014) and is recommended for the prevention and management of GDM (Colberg et al., 2016). Meta-analysis evidence has shown that engaging in physical activity both prior to and during pregnancy was significantly associated with lower odds of developing GDM (Mijatovic-Vukas et al., 2018; Tobias et al., 2011).

1.1.4 Negative perinatal health outcomes associated with GDM

GDM has been associated with a number of negative perinatal outcomes. Maternal outcomes can include caesarean delivery (Karasneh et al., 2021; Metzger et al., 2008; Ovesen et al., 2015; Roman et al., 2011; Yue et al., 2022), cardiovascular complications (McKenzie-Sampson et al., 2018; Zahid et al., 2022), and developing Type 2 Diabetes Mellitus (T2DM) later in life (Bellamy et al., 2009). Complications for the infant can include high birthweight (Cosson et al., 2022; Karasneh et al., 2021), shoulder dystocia (Ovesen et al., 2015), pre-term delivery (Karasneh et al., 2021; Yue et al., 2022), neonatal hypoglycaemia (Arimitsu et al., 2023) and a low Apgar score at birth (Kebapcilar et al., 2016). These outcomes all have negative implications in both the short and long term.

C-Section

An increased risk of birth via caesarean section (c-section) when diagnosed with GDM has been well documented (Karasneh et al., 2021; Metzger et al., 2008; Ovesen et al., 2015; Roman et al., 2011; Yue et al., 2022), with even greater risk in women with a high BMI (Langer et al., 2005; Roman et al., 2011; Yue et al., 2022). Findings from the Hyperglycaemia and Adverse Pregnancy Outcome (HAPO) study demonstrated a direct link between increased

BGLs and c-section risk, as well as high fasting glucose to be a predictor of high birthweight (Metzger et al., 2008). Birth via c-section is known to be associated with infant macrosomia (birth weight >4000 g) (Chen et al., 2023).

Cardiovascular complications

GDM is known to increase the risk of cardiovascular complications both at the time of delivery and in the years following. In 2022, Zahid et al. (2022) found that when adjusted for BMI, age, race and income, GDM remained independently associated with incidence of cardiovascular complications at delivery including stroke, preeclampsia, arrythmia and acute kidney injury (Zahid et al., 2022). While Zahid et al. (2022) looked at immediate effects of GDM on cardiovascular events, McKenzie-Sampson et al. undertook a retrospective cohort study looking at cardiovascular disease (CVD) risk and its association with GDM at a 25 year follow-up. Women who had GDM were more likely to be hospitalised for a cardiovascular event, and were at much higher risk for multiple CVD complications (McKenzie-Sampson et al., 2018). Diet is directly associated with the development of CVD (Reddy & Katan, 2004), so developing appropriate dietary patterns with dietetic intervention during pregnancy could reduce the risk of these diseases.

The HAPO study showed higher fasting BGLs to be associated with higher risk of pre-eclampsia (Metzger et al., 2008). This finding was reflected by Yogev et al. (2004) who found that 10% of women with GDM developed pre-eclampsia. The women who developed pre-eclampsia were more likely to be obese, had higher weight gain during pregnancy, and more severe cases of GDM (Yogev et al., 2004).

Type 2 Diabetes Mellitus

Women who have had a GDM affected pregnancy are at a significantly increased risk of developing T2DM postnatally (Bellamy et al., 2009). The 2009 meta-analysis by Bellamy et al. (2009) estimates that women with GDM are seven-times more likely to develop T2DM than those who experienced a euglycaemic pregnancy (Bellamy et al., 2009). As noted previously, the majority of genes identified to be associated with GDM are also significantly associated

with the development of T2DM (Pervjakova et al., 2022). The steepest incline in T2DM diagnosis appears to be in the five year period post-partum, however, it is difficult to ascertain the true prevalence of the development of T2DM after GDM due to the heterogeneity of follow-up in various studies (Kim et al., 2002) and poor postnatal screening (Sise et al., 2022). The risk of developing T2DM following GDM could potentially be minimised by maintaining a BMI below 25 kg/m^2, regular physical activity, smoking abstinence, and moderating alcohol consumption (Yang et al., 2022).

Macrosomia

Further literature on the association between GDM and macrosomia, or infants being large-for-gestational-age (LGA) (defined as a birthweight above the 90th percentile) (Brown & Chang, 2018) aligns with the results of the HAPO study (Metzger et al., 2008). Karasneh et al. (2021) found that women with GDM were more likely to give birth to macrosomic infants than those without a GDM diagnosis (Karasneh et al., 2021) and Cosson et al. (2022) found the risk of LGA to be higher with each categorical increase in plasma glucose levels, (Cosson et al., 2022). Similar to findings associated with risk of c-section, the risks associated with GDM are amplified by maternal obesity in relation to birthweight (Yue et al., 2022).

Shoulder dystocia

Shoulder dystocia is a birth complication that occurs when an infant's shoulders become stuck in the birth canal following delivery of the head, characterised by the need for further obstetric intervention to deliver the shoulders and body (Gottlieb & Galan, 2007). A Danish cohort study exploring perinatal outcomes associated with GDM in 398,623 women (9014 with GDM) found that a GDM diagnosis increased the risk of shoulder dystocia (Ovesen et al., 2015). The ACHOIS (Australian Carbohydrate Intolerance Study in Pregnant Women) trial also demonstrated that increased maternal blood glucose levels increased the risk of shoulder dystocia in infants, as well as identifying high infant birthweight as an independent risk factor for shoulder dystocia (Athukorala et al., 2007). This deems the relationship between GDM and shoulder dystocia unsurprising, considering the previously established relationship

between GDM and infant birthweight (Cosson et al., 2022; Karasneh et al., 2021; Metzger et al., 2008).

Apgar score

The Apgar Score is a newborn assessment method recorded for all births, assessing breathing, heart rate, muscle tone, response to stimulation and infant colour. The scoring system is out of 10 with two potential points assigned to each category. The score is calculated at one and five minutes after birth, with a score of 7-10 being considered normal, and a score below 7 indicating a need for continued monitoring and the potential need for intervention if this does not improve (American Academy of Pediatrics et al., 2006; Simon et al., 2023). A low Apgar score (between 0 and 3) at birth has been associated with increased neonatal mortality in both pre-term and full-term infants (Casey et al., 2001). Kebapcilar et al. (2016), found that infants born to women with GDM had a significantly lower Apgar score after both 1 minute and 5 minutes compared to women in the control group matched for age and BMI (Kebapcilar et al., 2016). Contrarily, data collected from 58,089 women in the Maine State Birth Records database showed that the newborns of women categorised as obese or morbidly obese were more likely to receive an Apgar score between 4 and 6 (out of 10) (Chen et al., 2010), but a GDM diagnosis did not appear to be associated with the Apgar Score (Yeagle et al., 2018). Ovesen et al. (2015) found a low Apgar score to be associated with GDM before, but not after, adjusting for potential confounding factors including maternal age and weight (Ovesen et al., 2015). A potential explanation for the relationship between low Apgar scores and GDM is oxidative stress. A case-control study of 119 women (81 with GDM) showed higher levels of maternal and cord blood neopterin, an inflammatory marker, being associated with lower Apgar scores in women with GDM, and higher levels shown in women who had GDM than those who did not (Ipekci et al., 2015). Kebapcilar et al. (2016) also showed that mean platelet volume was higher in women with GDM than those without, and higher maternal mean platelet volume in women with GDM was associated with a low Apgar score (Kebapcilar et al., 2016).

Neonatal hypoglycaemia

A recently published Japanese observational study found that 45% of infants born to mothers with GDM developed hypoglycaemia, with early pregnancy HbA1c and gestational weight gain being associated with the risk of its development (Arimitsu et al., 2023). This reflects earlier findings from the HAPO study which demonstrated that large increases in BGLs were associated with neonatal hypoglycaemia (Metzger et al., 2008), as well as Roman et al. (2011) who showed that maternal obesity in women with GDM was also associated with neonatal hypoglycaemia (Roman et al., 2011). Comparatively to Arimitsu et al. (2023), the National Women's Health Annual Clinical Report showed a more modest 10% of GDM pregnancies to result in neonatal hypoglycaemia over the last 20 years. However, the report does not provide a figure regarding how this value has trended during this time (National Women's Health, 2021).

Pre-term birth

Infants being born pre-term (<37 weeks' gestation) is a known adverse outcome associated with GDM (Karasneh et al., 2021; Yue et al., 2022). The risk of preterm delivery is thought to increase with increased BGLs during pregnancy (Hedderson et al., 2003), and is associated with higher HbA1c and systolic blood pressure (Diboun et al., 2020). A small study (n=79) on the link between GDM and pre-term birth showed that 78% of women who delivered pre-term gave birth via emergency caesarean (Preda et al., 2023). This demonstrates that the relationship may be between GDM and the need for intervention, rather than naturally occurring early labour.

Long term effects

Observational evidence shows that children born to mothers with GDM have greater likelihood of being obese later in life, or developing diabetes themselves (Bianco & Josefson, 2019). GDM has also been associated with children ages 18 to 60 months being at higher risk of developmental 'concern'. Greater risk within this category is associated with parental main income source being government welfare, and reduced risk with higher maternal educational

attainment, demonstrating insight into the social determinants of health in relation to GDM, and developmental metrics (Titmuss et al., 2022). As noted by Chu and Godfrey (2020), challenges lie in finding an independent relationship between GDM and longer-term infant outcomes due to the number of interacting socio-environmental factors (Chu & Godfrey, 2020).

1.2 Treatment of GDM

1.2.1 Overview of treatment strategies

The aim of GDM treatment is to maintain blood glucose levels within a normal range and facilitate appropriate maternal weight gain with the overarching goal to reduce negative perinatal outcomes for both the mother and infant (Farrar et al., 2017; Vääräsmäki, 2016). Optimal glycaemic targets for women with GDM remain undefined. First-line treatment for GDM involves diet and lifestyle advice but may progress to pharmaceutical treatments such as metformin or insulin where diet and lifestyle alone do not achieve treatment goals (Blumberg et al., 2018; Duarte-Gardea et al., 2018; Ministry of Health, 2014b).

Lifestyle

Lifestyle management of GDM can include education, diet, exercise, and self-monitoring of blood glucose levels (Duarte-Gardea et al., 2018; Ministry of Health, 2014b; Rasmussen et al., 2020). In a Cochrane systematic review, Brown et al. (2017) found lifestyle intervention to reduce rates of LGA, neonatal fat mass and incidence of post-natal depression in women with GDM. There was no clear evidence for the improvement of pre-eclampsia, development of T2DM, induction of labour or neonatal hypoglycaemia (Brown, Alwan, et al., 2017). Lifestyle interventions covered in this Cochrane review are relatively broad and do not note the specificity of dietetic input or medical nutrition therapy as a variable. What this does demonstrate, is that some of the advice that dietitians may give, for example, appropriate management of carbohydrate intake, education on diabetes management or advice on physical activity, could be effective at reducing LGA risk, neonatal fat mass, and achieving appropriate weight targets post-partum (which may be beneficial in preventing the development of T2DM). The majority of evidence described in this review was moderate or

low-quality, with the conclusion highlighting the necessity for further research into the identification of optimal interventions and how they should best be delivered.

Pharmacological treatment

Women with GDM whose blood glucose levels are not adequately managed with lifestyle intervention may be started on pharmacological treatments such as metformin (or another oral hypoglycaemic) and/or insulin (Duarte-Gardea et al., 2018; Ministry of Health, 2014b). A 2017 Cochrane review comparing insulin to other oral therapies showed no clear difference in perinatal outcomes between the two, suggesting that the decision may be a case of clinical judgement and maternal preferences (Brown, Grzeskowiak, et al., 2017). The New Zealand Clinical Practice Guidelines for GDM recommend taking a woman's preference and ability to self-manage medications into consideration when deciding on pharmacotherapy options (Ministry of Health, 2014b), accounting for the fact that oral agents are easy to take and do not require injection like insulin (Ghomian et al., 2019).

Combined lifestyle and pharmacological treatment

Two large randomised control trials by Crowther et al. (2005) and Landon et al. (2009) showed that treating women with dietary intervention, blood glucose self-monitoring and commencing insulin therapy as indicated was effective in improving several perinatal outcomes associated with GDM (Crowther et al., 2005; Landon et al., 2009). Crowther et al. (2005) showed that this style of treatment was associated with reduced rates of serious complications including death, shoulder dystocia, bone fracture and nerve palsy, and lower rates of pre-eclampsia. They also found that treating GDM resulted in infants being at reduced risk for being LGA, but at no increased risk for SGA. However, this did not result in a reduced rate of birth via c-section. Nutrition treatment in this intervention involved individualised medical nutrition therapy taking a woman's nutritional status and existing lifestyle habits into account. Ninety-two percent of women in the treatment group saw a dietitian during their pregnancy compared to 10% in the control group (Crowther et al., 2005). A key strength of this study is that dietary advice is treated as one piece of the puzzle, which is more applicable to real life scenarios and patients, but also provides a foundation for research into the effects

of dietetic input specifically. What this shows is that medical nutrition therapy is potentially influential in perinatal outcomes for women with GDM and warrants further research.

Landon et al. (2009) constructed a similar trial in which women with 'mild' GDM were randomised to dietary intervention, blood glucose self-monitoring and insulin therapy if needed, or usual pre-natal care that is non-specific to GDM. Many findings of this study reflected those of Crowther et al. (2005), in that treatment of GDM significantly lowered the risk of LGA infants, shoulder dystocia, pre-eclampsia and hypertension. Findings that differed include a significantly reduced risk of c-section for the treatment group, and no difference in serious perinatal outcomes including stillbirth or perinatal death and neonatal complications, including hyperbilirubinemia, hypoglycaemia, hyperinsulinemia, and birth trauma (Landon et al., 2009). With that being said, the paper notes that serious outcomes are often associated with more extreme cases of hyperglycaemia as demonstrated by the HAPO study (Metzger et al., 2008).

1.2.2 Definition of dietetic intervention

The New Zealand Dietitians Board defines a dietitian as a '*registered health practitioner who evaluates scientific evidence about food and nutrition and translates it into practical strategies'* (Dietitian's Board, 2017). Care delivered by a registered dietitian is also referred to as Medical Nutrition therapy (MNT), defined as '*the use of specific nutrition services to treat an illness, injury, or condition'* (American Dietetic Association, 1994). Dietitians in Aotearoa are trained to follow the Nutrition Care Process (NCP), an evidence-based cyclical process of care that comprises of assessment, diagnosis, intervention, and monitoring and evaluation stages. A core concept of the NCP is following up with patients as needed and adjusting their care based on the monitoring and evaluation of a patients progress from previous appointments (Lacey & Cross, 2002).

1.2.3 Current dietetic guidelines for GDM

Dietetic input is considered a first-line therapeutic strategy or 'cornerstone' of GDM management (Moreno-Castilla et al., 2016). The 2014 New Zealand clinical practice

guidelines for the management of GDM do not include a clear guideline on the involvement of a dietitian in the care of women with GDM. The guidelines present recommendations from other dietary interventions, some of which include individualised MNT, seeing a registered dietitian, or being offered dietary advice. What is not included is an evidence-based recommendation on the level of contact with a dietitian a woman with GDM should have to optimise management and outcomes (Ministry of Health, 2014b).

A 2017 survey on the dietetic management of GDM in Aotearoa showed that dietitians treating GDM were using a large range of guidelines to inform their recommendations, including international GDM nutrition practice guidelines and the New Zealand Ministry of Health Food and Nutrition Guidelines for Healthy Pregnant and Breastfeeding Women (not specific to women with GDM). Seventy-six percent of the dietitians surveyed expressed a want for "*New Zealand-specific evidence-based nutrition practice guidelines for gestational diabetes"* (Lawrence et al., 2017).

The Academy of Nutrition and Dietetics states that pregnant women diagnosed with GDM should be referred to and seen by a dietitian in order to manage their blood sugar levels and gestational weight gain, while still optimising their nutritional status to reduce the risk of negative perinatal outcomes (Duarte-Gardea et al., 2018). These guidelines recommend seeing a dietitian at least three times. These guidelines were implemented as an intervention in a randomised control trial by Reader et al. (2006) which included 215 women with GDM and compared clinical practice guidelines to usual care (Reader et al., 2006). The nutrition practice guidelines focused on establishing an MNT goal for each individual, self-monitoring of blood glucose and maintenance of a food plan and record, and establishment of a minimum of three nutrition visits during a GDM affected pregnancy. Those in the intervention group were less likely to require pharmaceutical management of their diabetes (24.6% vs 31.7%, p=0.05), and had lower HbA1c at follow-up, though this was not statistically significant (Reader et al., 2006). In a survey of dietitians in Aotearoa, Lawrence et al. (2017) showed that only 28% of dietitians surveyed reported seeing patients with GDM three or more times, with half of patients being seen only once (Lawrence et al., 2017). With that being said, the guidelines for frequency and duration of MNT visits are formed via consensus, meaning that expert opinion supports the recommendation, and clearly state that lack of evidence on the

optimal frequency of dietetic input associated with the improvement of perinatal outcomes (Duarte-Gardea et al., 2018).

1.2.4 Evidence for specific dietary interventions

Studies into the effects of nutrient or energy-specific dietary interventions have tended to be prescriptive dietary interventions that do not consider individual nutrition status (Han et al., 2017; Yamamoto et al., 2018). The 2017 Cochrane review by Han et al. (2017) looked at 19 randomised control trials on the types of dietary advice given to women and the association with improved perinatal outcomes. Types of dietary advice given included carbohydrate restriction, energy restriction, low versus high glycaemic index (GI) foods, DASH (Dietary Approaches to Stop Hypertension) diet (among others). Overall, no clear difference was found in the perinatal outcomes according to diet type (Han et al., 2017). Another meta-analysis of randomised control trials of dietary intervention on perinatal outcomes showed that intervention groups had a larger decrease in fasting and post-prandial BGLs, less need for pharmaceutical intervention and reduced infant birthweight (Yamamoto et al., 2018). However, a low quality of evidence surrounding these findings was reported, specifically relating to small sample size (Yamamoto et al., 2018).

In a randomised control trial comparing the effects of a diet with macronutrient distribution of 40% or 55% carbohydrate on initiation of insulin treatment, and secondary obstetric and perinatal outcomes, Moreno-Castilla et al. (2013) found no difference in outcomes between the two groups. A significant confounder in this trial was the 40% carbohydrate diet having a higher fat content to make the control and intervention diets isocaloric (Moreno-Castilla et al., 2013). This evidence suggests that general carbohydrate restriction may not be effective in managing GDM.

Overall, strong evidence supporting a particular dietary intervention for GDM is lacking. As identified by Lawrence et al. (2017), dietitians in Aotearoa are covering a wide range of dietary advice with their GDM patients, including carbohydrate type and distribution, not merely quantity, general healthy eating advice, dietary sources of carbohydrate, protein and fat, physical activity and appropriate weight gain during pregnancy (Lawrence et al., 2017). So, it

appears that specific dietary patterns are not being recommended in practice in Aotearoa, in line with the fact that women will all have individual nutrition needs during their pregnancy.

1.2.5 Evidence for Medical Nutrition Therapy in GDM

There is growing evidence that Medical Nutrition Therapy (MNT) provided for women with GDM leads to improved perinatal outcomes such as gestational weight gain (GWG), BGLs, macrosomia, LGA and jaundice (Mustafa et al., 2022; Perichart-Perera et al., 2009; Shi et al., 2016; Vestgaard et al., 2017). A retrospective cohort study in China, which spanned 5 years and included 488 women with GDM, examined the relationship between receiving MNT during a GDM-affected pregnancy and perinatal outcomes (Shi et al., 2016). Those who received MNT during pregnancy had lower average GWG, lower FBGLs and 2hr OGTT blood glucose results. These women were also half as likely to be prescribed insulin or require a caesarean section and were less likely to give birth to a macrosomic infant (9.77% vs 27.62%, p=<0.001). There were no significant differences in rates of pre-term birth, neonatal hypoglycaemia and pregnancy induced hypertension.

Perichart-Perera et al. looked at the effects of antenatal dietetic input on perinatal outcomes for women with both GDM and T2DM, with the GDM group being analysed separately. In this intervention, women were seen every two weeks by a dietitian, totalling on average 7.4 visits (Perichart-Perera et al., 2009). Those receiving the MNT intervention had lower rates of pre-eclampsia, maternal hospitalisation, low birth weight and neonatal death, but no difference was seen in the rates of macrosomia (Perichart-Perera et al., 2009). A critique of this intervention is that the mean energy intake for women in the MNT group was ~1500 kcal/day, which is a significant energy restriction for pregnant women, considering that the intervention outlined a minimum energy consumption of 1700 kcal/day (Perichart-Perera et al., 2009). This indicates that those receiving MNT may be inclined to excessively restrict their energy intake following GDM diagnosis, even under guidance of a registered dietitian. Furthermore, whether this level of dietetic input is required to have a positive impact on perinatal outcomes, or feasible outside of a research setting, is uncertain. In a national survey of dietetic practice in Aotearoa, Lawrence et al. (2017) found most dietitians reported seeing women with GDM twice during pregnancy (Lawrence et al., 2017).

Contrary to the findings of Perichart-Perera et al. (2009), Vestgaard et al. (2017) found that women with GDM receiving MNT were less likely to give birth to LGA infants than both women with GDM not receiving MNT or women without GDM (Vestgaard et al., 2017). There was a negative linear relationship between infant birthweight and length of time between the first visit with a dietitian and delivery (Vestgaard et al., 2017). This may indicate that MNT is most effective when delivered early during pregnancy. Early intervention with MNT could potentially have further benefits from the flow-on effects of lowering the incidence of LGA such as a reduced need for c-section and reduced risk of shoulder dystocia (Chen et al., 2023; Youssefzadeh et al., 2023). Although the number of appointments attended was not measured in this study, being seen earlier in pregnancy could indicate more chances for multiple follow-ups with a dietitian, or it could simply indicate the earlier in the pregnancy a dietitian intervenes, the greater chance the intervention has on influencing outcomes.

In a cohort of 313 women with GDM in Aotearoa, Mustafa et al. (2022) investigated adherence to clinical practice guidelines for treatment of GDM and its relationship to perinatal outcomes (Mustafa et al., 2022). In this cohort study, seeing a dietitian compared to not seeing a dietitian was associated with reduced hyperbilirubinemia in infants and lower incidence of LGA, as well as increased odds of infants between the 10th and 90th birthweight centiles. However, dietetic input was associated with increased pharmacological treatment for diabetes. It was noted that the increased likelihood of pharmaceutical management in women who have seen a dietitian may be due to the fact that women with more difficult to manage GDM may be more likely to be referred to a dietitian for support. In the ACHOIS trial, Crowther et al. (2005) investigated the effects of treating women with less severe GDM, or 'glucose intolerance in pregnancy' with medical nutrition therapy and adding pharmacological treatment as necessary. Compared to women receiving routine care, management with a combination of MNT and medication on an 'as required' basis appeared be the best strategy for improving perinatal outcomes (Crowther et al., 2005). Infants born to women in the intervention group had significantly lower odds of serious perinatal complications (OR = 0.33, Cl = 0.14, 0.75). This demonstrates the value of treating not only women with severe glucose impairment, but also women identified through a lower diagnostic threshold. While prioritising dietetic care for women with more difficult to manage GDM may be necessary

according to resourcing constraints, this highlights the importance of intervention at lower levels of glucose intolerance as well.

1.3 Level of dietetic input and GDM

1.3.1 Number/frequency of appointments

Increased frequency of dietetic appointments has shown to be effective at improving outcomes in both general diabetes and pregnancy settings, (Franz et al., 1995; Kulkarni et al., 1998; Robertson & Ladlow, 2018) both of which provide relevant evidence to the potential effects of MNT on GDM and its outcomes. However, some of the literature on this topic is dated and would benefit from being updated in a more relevant context considering the developments in MNT treatment of diabetes since then (Franz et al., 2003).

Kulkarni et al. (1998) and Franz et al. (1995) looked at the relationship between time with a dietitian and outcomes for Type 1 Diabetes Mellitus (T1DM) and T2DM respectively (Franz et al., 1995; Kulkarni et al., 1998). In those with T1DM, Kulkarni et al. found with the implementation of a set of nutrition practice guidelines, participants in the Nutrition Practice Guidelines group spent 63% more time with a dietitian than the 'usual care' control group. Participants in the intervention group and were seen by a dietitian on average three times as opposed to twice in the usual care group (Kulkarni et al., 1998). The intervention group had a greater proportion of participants with significant improvement in HbA1c compared to the control group (88% vs 53% p=0.03). Limitations of this study include the fact that the nutrition practice guidelines used are no longer available, so it is difficult to clearly define the intervention being provided. The study's small sample size of 54 reduces the power of the results, and the age of the study, considering its publication in 1998, means the types of advice dietitians were giving at this time may have evolved in the past 25 years (Franz et al., 2003). In 1995, Franz et al. compared the outcomes of those with T2DM who received 'basic nutrition care' versus a set of practice nutrition guidelines in a randomised clinical trial. Those in the basic care group received a single one-hour appointment with a dietitian in which they developed a nutrition care plan. The intervention group received an initial one-hour session as well as two more 30 to 45 minute follow up appointments in the following six weeks. Both groups saw an improvement in average HbA1c levels (10mmol/L in the intervention group

and 7mmol/L for basic care), and participants experienced statistically significant weight loss. A greater level of contact with a dietitian was associated with lower fasting plasma glucose as well as improved cholesterol levels over a six-month period (Franz et al., 1995). This study also shows that while multiple appointments may have a more significant impact on outcomes, a single education session can still provide value. Although this RCT was not conducted in a GDM-specific context, evidence that MNT can improve glycaemic outcomes provides a basis for the hypothesis that it can improve perinatal outcomes relating to GDM. The HAPO study demonstrates that hyperglycaemia in pregnancy can result in poorer perinatal outcomes such as high infant birthweight, c-section, neonatal hypoglycaemia and pre-eclampsia (Metzger et al., 2008), so if MNT can be used to manage BGLs, it may improve perinatal outcomes that result from hyperglycaemia in GDM.

Robertson et al. (2018) looked at the relationship between the number of dietetic appointments and gestational weight gain in 174 pregnant women with a BMI of 35 or above (Robertson & Ladlow, 2018). Women experienced a statistically significant lower weight gain if they attended three or more MNT appointments, but there was no further benefit beyond three appointments. At least three appointments during a GDM affected pregnancy is recommended by the Academy of Nutrition and Dietetics, (Duarte-Gardea et al., 2018). As discussed, the minimum of three appointments suggested are based on Reader et al.'s (2006) randomised control trial, demonstrating that women were less likely to require medical management of their GDM when these guidelines were followed. However, it is important to note that the control group, on average, attended the same number of appointments as the intervention group (3.8 ± 2.0 vs 3.5 ± 2.0), so the impact of appointment frequency cannot be assessed from this study. Understanding if there is an optimal number of appointments and at what point a higher frequency does not result in improved outcomes is valuable in a practical sense to assess the cost-benefit ratio of the intervention.

To our knowledge, there is currently no published research evaluating the level of dietetic input, in terms of number of appointments or contact time, on perinatal outcomes. Yuan et al. (2020) investigated the effects of a time-intensive 12-hour 'comprehensive nutrition care' programme compared with 'traditional one-time nutritional guidance' on perinatal outcomes for women with GDM in China (Yuan et al., 2020). The programme included a full day from

7am to 7.30pm of nutrition education with a dietitian, guided exercise and provision of three nutritious meals and two snacks, the portions of which were specifically calculated to suit individual patients nutrition needs as opposed to a standard prescriptive diet (Yuan et al., 2020). Those in the intervention group had a lower average gestational weight gain, lower average 2hr post-prandial glucose, reduced gestational hypertension, pre-term labour, as well as lower average birth rate and reduced risk of macrosomia. There was no difference between groups in the incidence of birth via c-section. This presents good evidence for 'contact time' spent with a dietitian or diabetes educator, however a 12 hour block of time is unlikely to be a realistic intervention for all women (though loss to follow-up is reduced for a one-time intervention). This study also demonstrates that group education can be successful but did not compare findings to a non-group education control.

1.3.2 Group vs individual appointments

Group nutrition counselling is a common method used to deliver nutrition education to multiple people to optimise resources when time, financial or staffing constraints are at play. Barnes et al. (2018) explored the effects of group compared to individual dietetic appointments as initial dietetic input. After the initial group or individual session, both groups received an individual, follow-up appointment. Women were matched for age, ethnicity and OGTT results between groups, but those receiving group education had a lower average HbA1c at diagnosis. Barnes et al. (2018) found an initial group education session to be a significant predictor of insulin therapy, which was commenced if glycaemic targets were not met in the two weeks following the intervention (Barnes et al., 2018). This finding was despite the fact that the group session was about twice as long as the individual session, however group therapy also had lower attendance than individual nutrition therapy. These two factors have the potential to confound results and present a less clear indication as to the true difference in outcomes between attending a group or individual nutrition appointment. However, these findings may suggest that individual MNT could be more effective and less time consuming for women with GDM compared to group sessions. Those who received an individual initial appointment were better able to manage their BGLs through diet. Otherwise, there was no difference in any other outcome between the two groups. Regardless of if initial education was individual or in a group, women all received an individual dietetic follow-up, which led Barnes et al. (2018) to conclude that both appointment types can be effective in

managing GDM if supplemented by at least one individual follow-up appointment. If group education proves to effectively communicate information that women need to manage their GDM, it could be an effective use of dietetic resources.

In a study of newly diagnosed women with GDM, Murphy et al. (2004) explored differences in knowledge of diabetes and understanding of appropriate nutrition during pregnancy in group compared to individual nutrition education sessions. Participants knowledge was assessed via a questionnaire that was carried out before, immediately following, and one week after the nutrition education session. Both groups showed a significant increase in knowledge immediately following the session and demonstrated retention of this knowledge a week later (Murphy et al., 2004). While it is valuable to know that women's knowledge can improve through both methods, this study is limited in that it does not investigate how well this knowledge is being applied through dietary patterns and GDM outcomes. Group education in this setting saved 27 hours of dietitian time over 35 women which could lead to greater efficiencies and healthcare cost-savings (Murphy et al., 2004).

Two recent studies investigating the effects of group versus individual nutrition counselling on obesity and related comorbidities presented conflicting evidence on the comparative effectiveness of the two intervention styles. Gajewska et al. (2019) found in hypertensive and overweight adults that those who received individual nutrition education had more improvements in weight, waist-circumference and blood pressure. Fasting and 2-hour OGTT glucose level and insulin resistance were reduced when compared to their counterparts receiving group nutrition education (Gajewska et al., 2019). While this study does not look into GDM specifically, it does identify improvements in metrics related to GDM such as BGLs and insulin resistance, and there are many overlapping risk factors for both conditions. A population limitation of this study is that the average age of participants was 60 years old, which is not similar to the age demographic of women with GDM. The programme consisted of six education sessions which may not be feasible outside of the research environment.

Bolognese et al. (2020) carried out a similar clinical trial in which 74 women with a BMI of more than 25 kg/m^2 were randomised to receive 12 weeks of group or individual nutrition counselling. However, they contradict the findings of Gajewska et al. (2019), demonstrating

that both interventions were effective at reducing BMI and overall energy intake from all food groups, but neither intervention affected insulin use or HbA1c levels (Bolognese et al., 2020). Again, this study is not specific to a GDM population and targets an older population group (40-59 years old), but there are certainly population overlaps considering that overweight and obesity are predictors for developing GDM. Bolognese et al. (2019) does show the effects of nutrition education on outcomes relevant to a GDM population and, most importantly, it demonstrates behaviour change outcomes (reduced energy intake) as a result of intervention. There was no difference in diabetic biomarkers identified, however in a GDM management intervention this may differ if managing blood sugars was more of a focus. Considering that there were no differences in outcome between the two groups, if both interventions prove to be similarly effective, in a real-life context, patient referrals to either group or individual counselling could be based on preference or healthcare resourcing without the concern of compromising outcomes.

1.3.3 Telehealth vs in person

Delivering health and nutrition interventions via technology such as apps, video-calling and telephone became more necessary than ever during the COVID-19 pandemic. As a more digital way of life comes to the forefront, the health system must be nimble and adaptable to meet the demands of its population. This raises the question, can telehealth nutrition be effective, and can it be comparatively effective to face-to-face programmes?

Literature on the effects of app or webchat-based treatment has varying conclusions regarding its effect on the perinatal outcomes of GDM. A systematic review of small studies during the COVID-19 pandemic demonstrated that a telemedical nutrition approach can be effective at lowering HbA1c (Eberle & Stichling, 2021). Xie et al. (2020) found that those receiving telemedical support for GDM had a lowered risk of c-section, pre-eclampsia, pre-term birth, neonatal asphyxia and macrosomia, however the intervention in this study involved a multidisciplinary approach, not just nutrition education (Xie et al., 2020). This study also concluded that there were better effects seen when the interventions were delivered via apps women already used in everyday life rather than online tools and apps that had been designed specifically to deliver telemedical interventions. Contrary to the findings

of Xie et al. (2020), Rasekaba et al. (2018) found in a randomised control trial of 95 women with GDM that telehealth input on top of usual care had no effect on GDM outcomes such as incidence of caesarean section or LGA. However, receiving telehealth intervention was associated with improved the glycaemic control of women involved in the study (Rasekaba et al., 2018) compared to those in the 'usual care' control group.

Lim et al. investigated the effects of a telephone lifestyle-based diabetes prevention programme in women with a history of GDM after they had given birth, comparing participant engagement between telephone and group nutritional consultation (Lim et al., 2017). The programme was delivered by trained coaches and facilitators. Women receiving telephone consultations were more likely to be engaged in the programme than those receiving group education, with the metric for engagement being attendance to at least 80% of sessions. Women who perceived their risk of developing diabetes to be higher in a self-administered questionnaire at baseline were more likely to be engaged with the programme, and those who were engaged achieved a more significant change in weight and waist circumference. Lim et al. (2017) proceeds to discuss that the telephone-delivered programme reduced some of the perceived barriers to participation such as finding childcare, scheduling, and confidentiality in a group setting. Childcare and scheduling may also be interpreted as barriers to attending in-person appointments.

A 2019 randomised control trial investigated the effect of telemedicine on T2DM management compared to 'usual care' (Benson et al., 2019). The intervention consisted of MNT-based phone calls delivered by dietitians and followed the Nutrition Care Process (Lacey & Cross, 2002). Counselling techniques included the Health Belief Model (Rosenstock, 1974) and the Transtheoretical Model of Behaviour Change (Prochaska & Velicer, 1997) both of which have been adopted in dietetic practice (Rosenstock, 1982; Spencer et al., 2007). Neither the intervention nor the control group had a statistically significant change in HbA1c, but the group receiving telehealth improved their intake of fruits and vegetables, adherence to diabetes medication, and had achieved more optimal diabetes measures than the control group. The control group in this study received no nutrition intervention rather than

comparing telehealth to a face-to-face intervention, however in a real-life context, perhaps women with GDM who are seen via telehealth may not be seen otherwise.

While, again, not in a GDM population but with outcomes relevant to GDM, Harrigan et al. (2016) compared the effects of nutrition and weight loss counselling over the phone or in-person in a randomised control trial of women who have been treated for breast cancer (Harrigan et al., 2016). A non-intervention control group was also included in the study. Women in both intervention groups lost weight, increased physical activity, fibre, and fruit and vegetable intake compared to the control group but neither intervention had an effect on blood glucose levels or need for insulin (though blood sugar management was not specifically counselled). Both intervention groups were shown to have similar effect (Harrigan et al., 2016).

1.4 Research gap

While there are some inconsistencies in the literature regarding which perinatal outcomes can be affected or improved by dietetic input in a GDM-affected pregnancy, there is an evident theme of the benefits of MNT. What these papers do not provide is evidence of a relationship between GDM outcomes and level of dietetic input, prompting further investigation into the optimal level of care to inform more concrete guidelines and optimise dietetic resources.

As identified, there is a clear gap in the literature investigating the relationship between attending group or telehealth dietitian appointments and perinatal outcomes related to GDM, especially when compared to the effects of attending individual in-person appointments. Having a broader range of options available can make nutrition care more accessible to many women, increasing health equity in Aotearoa, but it is important to develop a body of evidence to ensure alternative interventions are achieving the desired outcomes.

1.5 Research aim

The aim of this research is to describe the level of dietetic input received by women diagnosed with GDM at Te Toka Tumai Auckland between 1st July 2022 and 31st December 2022, to determine if dietetic input leads to improved outcomes and whether there is an optimal level of input associated with improved perinatal outcomes.

1.6 Research objectives

1. To describe the level of dietetic input received by women diagnosed with GDM at Te Toka Tumai Auckland.
2. To determine if there are any differences in perinatal outcomes associated with GDM between those who received dietetic input during their pregnancy and those who did not.
3. To determine if there are any differences in perinatal outcomes according to the total number of dietetic appointments attended during a GDM affected pregnancy.
4. To determine if there are any differences in perinatal outcomes associated with GDM and the modality of treatment delivery whether that be individual in-person, telehealth or group education.

Chapter 2. Methods

2.1 Study population

This retrospective cohort study included women with a diagnosis of GDM who gave birth at Te Toka Tumai Auckland City Hospital between 1st July 2022 and 31st December 2022. The study population was identified via extraction of National Health Identifiers (NHIs) for women with a diagnosis of GDM, provided by the Women's Health Intelligence Unit at Te Toka Tumai Auckland. Women at Te Toka Tumai Auckland are diagnosed with GDM according to the Screening for Diabetes in Pregnancy protocols used at Te Toka Tumai Auckland ((National Women's Health, 2022) see appendices C, D, E). Briefly, women were considered to have a diagnosis of GDM if they met any of the following criteria: a blood glucose level of ≥5.5 mmol/L fasting or ≥9.0 mmol/L at 2 hours following a 75 g Oral Glucose Tolerance Test (OGTT) or ≥11.1 mmol/L 1-hour post 50 g Oral Glucose Challenge Test (Polycose test), HbA1c ≥ 41 mmol/mol, or if a women had elevated blood glucose readings (fasting >5.0mmol/L over several days, >6.0 mmol/L post-prandial over several days, more than one reading >6.5 mmol/L), typically following identification of LGA on a fetal growth scan. Women with multiple pregnancies were excluded from this study.

2.2 Data extraction

Using the list of NHIs classified as having GDM according to the criteria above, the Women's Health Intelligence Unit at Te Toka Tumai Auckland extracted demographic and clinical data from their database including maternal age at delivery, maternal ethnicity, New Zealand Deprivation Index (NZ Dep2018) (Atkinson, 2019), the date, time and method of delivery, infant birthweight, Apgar score at 1 and 5 minutes, parity, estimated due date and gestation at delivery. The total number of dietetic appointments each women attended, the appointment type (individual in-person, telehealth or Group Teach appointment), the earliest and latest body weights recorded during their pregnancy, the method of GDM diagnosis (2hr OGTT, HbA1c or elevated random blood glucose readings), use of medication such as insulin or metformin, incidence of shoulder dystocia, neonatal hypoglycaemia, and infant birthweight centile was manually extracted by the author from clinical records on Healthware, Badgernet and Regional Clinical Portal at Auckland City Hospital. Attendance to any of the

three types of dietetic appointment was recorded if attendance was confirmed in their clinical notes on Badgernet.

2.3 Covariates

Maternal age was recorded and categorised as follows: 18 - 24, 25 - 29, 30 - 34, 35 - 39, and ≥40 years. Ethnicity was categorised according to Statistics New Zealand coding criteria (Statistics New Zealand, 2005) into Māori, Pacific Peoples, Asian, Indian, European and MELAA (Midde Eastern, Latin American, African), with Indian ethnicity separated from Asian to reflect the GDM ethnicity reporting presented in the National Women's Health Annual Clinical Report (National Women's Health, 2021). Deprivation index deciles were categorised into quintiles (1 being least deprived, 5 being most deprived) (Atkinson, 2019). Early pregnancy BMI was categorised as <18.5 kg/m^2, 18.5 - 24.9 kg/m^2, 25 - 29.9 kg/m^2, and ≥30 kg/m^2. Appropriate gestational weight gain was identified following the New Zealand Ministry of Health Guidance for Healthy Weight Gain in Pregnancy (informed by the Institute of Medicine Weight Gain during Pregnancy recommendations) – 12.5-18 kg if BMI of <18.5 kg/m^2, 11.5-16 kg if BMI of 18.5 – 24.9 kg/m^2, 7-11.5 kg if BMI of 25 – 29.9 kg/m^2 and 5-9 kg if BMI of ≥30 kg/m^2(Ministry of Health, 2014a; Rasmussen & Yaktine, 2009). Large-for-gestational-age (LGA) and small-for-gestational-age (SGA) infants were identified if their birthweight fell above the 90th or below the 10th centile respectively. Neonatal hypoglycaemia was identified if an infant had a blood glucose reading of <2.6 mmol/L at or around the time of birth (within 1-hour and up to 12-hours after birth or up to 12-hours after the last low level) (Starship, 2019).

2.4 Statistical analyses

Maternal baseline characteristics, maternal and neonatal outcomes are reported as frequency (%) for categorical variables. Continuous variables are reported as mean (standard deviation (SD)) or median (interquartile range (IQR)) for normal and non-normal distribution respectively. Missing values for any characteristics or outcomes are not included in the data tables. Fisher's Exact Test, chi-squared, Mann-Whitney U test, Kruskal-Wallis test, and unadjusted and adjusted logistic regression were used to compare differences in maternal characteristics and perinatal outcomes according to dietetic input (number of appointments

and mode of appointment). Results are presented as odds ratios (OR), adjusted odds ratios (aOR) and 95% confidence intervals (95% CI). The following variables were included in the adjusted model as potential confounders to perinatal outcomes: maternal age at delivery, maternal ethnicity, deprivation quintile, early pregnancy BMI, GDM in a previous pregnancy, primigravida, early pregnancy HbA1c and method of GDM diagnosis (positive 2hr OGTT, raised HbA1c, LGA with an elevated random blood glucose, or positive polycose as described above). Variables included in the adjusted model were assessed for multicollinearity using Variance Inflation Factor (VIF). A variable was excluded from the model if the VIF exceeded 10 (Midi & Rana, 2010). R version 4.3.1 (2023-06-16) (R Core Team, 2023) was used to conduct statistical analyses. A two-sided p-value of <0.05 was considered statistically significant.

2.5 Ethics

This study was granted ethical approval by Auckland Health Research Ethics Committee (AHREC) on the 8th of December 2022 (AH24942) (see appendices A, B).

Chapter 3. Results

Of the 2972 women who gave birth at Te Toka Tumai Auckland between 1st July and 31st December 2022, 380 (12.8%) women had a documented diagnosis of GDM according to Te Toka Tumai Auckland criteria, a singleton pregnancy and were included in this study. Socio-economic, health and perinatal data for these women are displayed in Table 1. The highest presentation of GDM occurred in Asian (31.3%, n=119) and Indian (24.5%, n=93) ethnicities, while the lowest representation occurred in women of Māori and MELAA ethnicities (both 6.1%, n=23). GDM was more prevalent in the highest deprivation quintile (28.2%, n=107), and in women with a BMI of $\geq$30 kg/m^2 (40%, n=144). Thirty-nine percent of GDM cases were diagnosed via a positive 2hr-OGTT result (n=146), followed by high random blood glucose levels (31%, n=118) and HbA1c above 41 mmol/mol (29%, n=109).

Over half of women saw a dietitian during their GDM affected pregnancy (58.2%, n=221). Of those who saw a dietitian, the majority (70.1%, n=155) saw a dietitian once, and 9.5% (n=20) saw a dietitian three or more times (Table 1). There were no significant differences in maternal demographics between those who received input from a dietitian and those who did not, or according to the total number of dietetic appointments attended during the index pregnancy. However, there were significant differences in the level of dietetic input received according to method of GDM diagnosis (p=<0.001).

Table 1. *Characteristics of women diagnosed with GDM who gave birth at Te Toka Tumai Auckland between 1st July and 31st December 2022.*

		Received dietetic input			Number of dietetic appointments			
	Total	No	Yes		One	Two	Three or more	
n (%)	(n=380)	159 (41.8)	221 (58.2)	p-value	155 (40.8)	46 (12.1)	20 (5.3)	p-value
Age group (years)				0.677				0.277
18 - 24	20 (5.3)	11 (6.9)	9 (4.1)		8 (5.7)	1 (2.2)	0 (0.0)	
25 - 29	64 (16.8)	25 (15.7)	39 (17.7)		32 (20.7)	6 (13.0)	1 (5.0)	
30 - 34	149 (39.2)	60 (37.7)	89 (40.3)		65 (41.9)	17 (37.0)	7 (35.0)	
35 - 39	115 (30.3)	51 (32.1)	64 (29.0)		40 (25.8)	17 (37.0)	7 (35.0)	
≥ 40	32 (8.4)	12 (7.6)	29 (13.1)		10 (6.5)	5 (10.9)	5 (25.0)	
Primigravida				0.655				0.848
Yes	176 (46.3)	71 (44.7)	105 (47.5)		75 (48.4)	22 (47.8)	8 (40.0)	
No	204 (53.7)	88 (55.4)	116 (52.5)		80 (51.6)	24 (52.2)	12 (60.0)	
History of GDM				0.850				0.959
Yes	57 (15.0)	25 (15.7)	32 (14.5)		24 (15.5)	6 (13.0)	2 (10.0)	
No	323 (85.0)	134 (84.3)	189 (85.5)		131 (84.5)	40 (87.0)	18 (90.0)	
Ethnicity				0.202				0.201
Māori	23 (6.1)	13 (8.2)	10 (4.5)		7 (4.5)	1 (2.2)	2 (10.0)	
Pacific Peoples	62 (16.3)	34 (21.4)	28 (12.7)		23 (14.8)	4 (8.7)	1 (5.0)	
Asian	119 (31.3)	44 (27.7)	75 (34.0)		51 (32.9)	14 (30.4)	10 (50.0)	
Indian	93 (24.5)	31 (19.5)	62 (28.0)		42 (27.1)	15 (32.6)	5 (25.0)	
European	60 (15.8)	29 (18.2)	31 (14.0)		21 (13.6)	8 (17.4)	2 (10.0)	
MELAA	23 (6.1)	8 (5.0)	15 (6.7)		11 (7.1)	4 (8.7)	0 (0.0)	

Deprivation Index				0.959			0.963
1 to 2	42 (11.1)	18 (11.3)	24 (10.9)		18 (11.6)	3 (6.5)	3 (15.0)
3 to 4	77 (20.3)	32 (20.1)	45 (20.4)		29 (18.7)	11 (23.9)	5 (25.0)
5 to 6	81 (21.3)	38 (23.9)	43 (19.5)		33 (21.3)	7 (15.2)	3 (15.0)
7 to 8	73 (19.2)	28 (17.6)	45 (20.4)		32 (20.7)	9 (19.6)	4 (20.0)
9 to 10	107 (28.2)	43 (27.0)	64 (29.0)		43 (27.7)	16 (34.8)	5 (25.0)
BMI (kg/m^2)				0.082			0.079
<18.5	8 (2.2)	1 (0.7)	7 (3.3)		6 (4.1)	0 (0.0)	1 (5.0)
18.5 - 24.9	110 (30.6)	47 (32.4)	63 (29.4)		41 (27.7)	12 (26.1)	10 (50.0)
25 - 29.9	97 (27.0)	33 (22.8)	64 (30.0)		41 (27.7)	18 (39.1)	5 (25.0)
≥30	144 (40.1)	64 (44.1)	80 (37.4)		60 (40.5)	16 (34.8)	4 (20.0)
Method of GDM diagnosis				**<0.001**			**<0.001**
OGTT	146 (39.0)	39 (24.8)	107 (48.9)		76 (49.4)	23 (51.1)	8 (40.0)
LGA/BGL	118 (31.4)	77 (49.0)	41 (18.7)		33 (21.4)	6 (13.3)	2 (10.0)
HbA1c	109 (29.0)	41 (26.1)	68 (31.1)		43 (27.9)	15 (33.3)	10 (50.0)
Polycose	3 (0.8)	0 (0.0)	3 (1.4)		2 (1.3)	1 (2.2)	0 (0.0)

GDM, Gestational Diabetes Mellitus; MELAA, Middle Eastern/Latin American/African; BMI, Body Mass Index; OGTT, Oral Glucose Tolerance Test; LGA, Large-for-gestational-age; BGL, Blood glucose level; Missing values have not been included in column %, *P<0.05 when compared with 0 appointments, **P<0.005 when compared with 0 appointments; p-value calculated from chi-squared test or Fisher's Exact. Diagnostic criteria for method of GDM diagnosis: OGTT - blood glucose level of ≥5.5mmol/L fasting or ≥9.0mmol/L at 2 hours following a 75g glucose load, LGA/BGL – fasting blood glucose >5.0mmol/L over several days, >6.0mmol/L post-prandial over several days, more than one reading >6.5mmol/L), HbA1c – HbA1c ≥ 41 mmol/mol, Polycose test – blood glucose levels ≥11.1mmol/L 1-hour post 50g glucose load.

***Table 2**. Maternal outcomes by dietitian attendance*

		Received dietetic input			Number of dietetic appointments			
	Total	No	Yes	p-value	One	Two	Three or more	p-value
Maternal outcomes	n = 380	159 (41.8)	221 (58.2)		155 (40.8)	46 (12.1)	20 (5.3)	
Gestational weight gain (kg)	9.35 (5.1, 14.0)	10.50 (6.5, 15.0)	8.90 (4.5, 12.5)	**0.005**	9.15 (5.2, 13.4)	8.19 (3.6, 12.3)	5.25 (1.4, 9.3)*	**0.006**
Appropriate GWG				0.169				0.053
Yes	72 (22.7)	22 (18.2)	50 (25.5)		40 (30.3) *	8 (18.2)	2 (10.0)	
No	245 (77.3)	99 (81.8)	146 (74.5)		92 (69.7)	36 (81.8)	18 (90.0)	
Commenced Medication				**<0.001**				**<0.001**
Yes	300 (79.0)	103 (64.8)	197 (89.1)		140 (90.3) **	37 (80.4)	20 (100.0) **	
No	80 (21.1)	56 (35.2)	24 (10.9)		15 (9.7)	9 (19.6)	0 (0.0)	
Incidence of caesarean				0.123				0.430
Yes	179 (47.1)	67 (42.1)	112 (50.7)		78 (50.3)	24 (52.2)	10 (50.0)	
No	201 (52.9)	92 (57.9)	109 (49.3)		77 (49.7)	22 (47.8)	10 (50.0)	

GWG, Gestational Weight Gain; p-value calculated from Fisher's exact or chi-squared test for categorical variables and Mann-Whitney U test or Kruskal-Wallis and Dunn-Bonferroni post-hoc test for continuous variables; P<0.05 considered statistically significant; data presented as n (%) for categorical variables and median (IQR) for continuous variables; *P<0.05 when compared with 0 appointments in separate analysis,**P<0.005 when compared with 0 appointments in separate analysis.

Data were available to calculate GWG for 317 women. When analysed with the Mann-Whitney U test, median gestational weight gain (kg) was significantly lower in those who had seen a dietitian compared to those who had not (8.9 kg vs 10.5 kg, p = 0.005), as well as significantly different between the number of dietetic appointments where lower weight gain was seen with more dietetic appointments (9.15 kg, 8.19 kg and 5.25 kg for one, two and three or more appointments respectively, p = 0.006) (Table 2). Median gestational weight gain was significantly lower in those who had attended three or more compared to no appointments (5.3 kg vs 10.5 kg, p=0.016). Overall, 22.7% of women with GDM gained weight within Ministry of Health recommendations during their pregnancy (Table 2). Although not statistically significant, a greater proportion of women who saw a dietitian gained weight according to recommendations when compared to women who did not see a dietitian. (Table 2). When analysed according to number of appointments with a dietitian, women who saw a dietitian once compared to those who did not see a dietitian had significantly higher rates of appropriate GWG (30.3% vs 22.7%, p=0.036). Seeing a dietitian was associated with a higher incidence of commencing diabetes medication such as insulin and metformin during pregnancy (89.1% vs 64.85, p<0.001). All (n = 20) women who saw a dietitian three or more times were prescribed diabetes medication. Dietetic input was not associated with any difference in the incidence of birth via c-section (Table 2).

Unadjusted and adjusted odds of maternal perinatal outcomes according to dietetic appointment attendance are displayed in Table 3. There was no significant relationship between odds of achieving appropriate gestational weight gain and dietetic input in the unadjusted analysis, but after adjusting for maternal age at delivery, maternal ethnicity, deprivation quintile, early pregnancy BMI, previous GDM, primigravida, early pregnancy HbA1c, and diagnosis method, those who had dietetic input during pregnancy were twice as likely to gain an appropriate amount of weight based on their early pregnancy BMI compared to those who received no dietetic input (aOR =2.00, 95% CI = 1.07, 3.90). In both the unadjusted and adjusted model, seeing a dietitian once was associated with increased odds of appropriate GWG compared to those who did not see a dietitian (OR 1.96, 95% CI 1.09, aOR 3.58 and 2.58, 95% CI 1.33, 5.15 respectively). There was a significantly higher odds of being prescribed diabetes medication in women seeing a dietitian compared to those who

did not see a dietitian in both unadjusted and adjusted models (OR 4.46, 95% CI 2.65, 7.73 and aOR 3.37, 95% CI 1.70, 6.85 respectively) (Table 3).

Table 3. *Unadjusted and adjusted odds ratio of maternal outcomes comparing attendance to one, two or three or more appointments with no attendance.*

	Received dietetic input		**One appointment**		**Two appointments**		**Three or more appointments**	
Maternal outcomes	**OR (95% CI)**	**aOR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**
Appropriate GWG	1.54 (0.89, 2.75)	2.00 (1.07, 3.90)*	1.96 (1.09, 3.58)*	2.58 (1.33, 5.15)*	1.0 (0.39, 2.37)	1.34 (0.48, 3.54)	0.5 (0.76, 1.91)	0.47 (0.07, 2.03)
Commenced medication	4.46 (2.65, 7.73)**	3.37 (1.70, 6.85)**	5.01 (2.78, 9.76)**	4.64 (2.14, 10.71)**	2.24 (1.04, 5.24)*	1.05 (0.40, 2.90)	NA	NA
C-section	1.41 (0.94, 2.13)	1.53 (0.93, 2.53)	1.39 (0.89, 2.18)	1.56 (0.92, 2.66)	1.50 (0.78, 2.91)	1.41 (0.66, 3.03)	1.37 (0.54, 3.53)	1.54 (0.55, 4.30)

GWG, Gestational Weight Gain; OR, Odds Ratio; aOR, Adjusted Odds Ratio; Adjusted odds ratio calculated from adjusted logistic regression model (maternal age at delivery, maternal ethnicity, deprivation quintile, early pregnancy BMI, previous GDM, primigravida, early pregnancy HbA1c, diagnosis method); *P<0.05; all odds ratios compared with 0 appointments. *NA,* odds ratio unable to be calculated from logistic regression due to frequency of 0

***Table 4**. Neonatal outcomes according to frequency of dietetic input in infant born to women with a GDM affected pregnancy*

	Received dietetic input				Number of dietetic appointments			
	Total	**No**	**Yes**	**P-value**	**One**	**Two**	**Three or More**	**P-value**
Neonatal outcomes	n=380	n=159 (41.8)	n=221 (58.2)		155 (40.8)	46 (12.1)	20 (5.3)	
Infant birthweight (g)	3282 (2950, 3600)	3440 (3205, 3690)	3130 (2830, 3530)	**<0.001**	3120 (2842, 3560)**	3152 (2834, 3466)**	3008 (2828, 3242)**	**<0.001**
LGA				**0.017**				**0.017**
Yes	48 (13.3)	28 (18.7)	20 (9.4)*		18 (12.2)	1 (2.3) *	1 (5.0)	
No	314 (86.7)	122 (81.3)	192 (90.6)		130 (87.8)	43 (97.7)	19 (95.0)	
SGA				**0.022**				0.061
Yes	36 (10.0)	8 (5.3)	28 (13.2)		19 (12.8) *	6 (13.6)	3 (15.0)	
No	326 (90.1)	142 (94.7)	184 (86.8)		129 (87.2)	38 (86.4)	17 (85.0)	
Neonatal Hypoglycaemia				0.401				0.402
Yes	125 (39.4)	46 (36.2)	79 (41.6)		58 (43.3)	17 (42.5)	4 (25.0)	
No	192 (60.6)	81 (63.8)	111 (58.4)		76 (56.7)	23 (57.5)	12 (75.0)	
Shoulder dystocia				**0.031**				0.173
Yes	10 (2.6)	8 (5.0)	2 (0.9)		2 (1.3)	0 (0.0)	0 (0.0)	
No	370 (97.4)	151 (95.0)	219 (99.1)		153 (98.7)	46 (100.0)	20 (100.0)	
Admission to NICU				1				0.879
Yes	35 (9.2)	15 (9.4)	20 (9.1)		16 (10.3)	3 (6.5)	1 (5.0)	
No	345 (90.8)	144 (90.6)	201 (91.0)		139 (89.7)	43 (93.5)	19 (95.0)	
1-minute Apgar Score				0.914				0.190
≥7	341 (90.7)	145 (91.2)	196 (90.3)		141 (92.8)	37 (82.2)	18 (90.0)	
<7	35 (9.3)	14 (8.8)	21 (9.7)		11 (7.2)	8 (17.8)	2 (10.0)	
5-minute Apgar Score				0.925				0.832

≥7	365 (97.1)	155 (97.5)	210 (96.8)	147 (96.7)	43 (95.6)	20 (100.0)
<7	11 (2.9)	4 (2.5)	7 (3.2)	5 (3.3)	2 (4.4)	0 (0.0)

P <0.05 is considered statistically significant; LGA, Large for Gestational Age; NICU, Neonatal Intensive Care Unit; SGA, Small for Gestational Age; Missing values have not been included in table %; p-value calculated from Fisher's exact or chi-squared test for categorical variables and Mann-Whitney U test or Kruskal-Wallis and Dunn-Bonferroni post-hoc test for continuous variables; data presented as n (%) for categorical variables and median (IQR) for continuous variables; **p<0.005 when compared to 0 appointments in separate analysis, *p<0.05 when compared to 0 appointments in separate analysis.

Table 4 describes infant outcomes according to dietetic attendance. Median infant birthweight was higher in infants born to women who had not seen a dietitian when compared with those born to women who had (3440 g vs 3130 g, p<0.001), (Table 4), and significantly higher when compared to infants born to women with GDM who attended one, two or 3 or more appointments (3120 g, p<0.005, 3152 g, p<0.005, 3008 g, p<0.005 respectively). Incidence of LGA was 13.3% in infants born to women with GDM within this cohort. Infants born to women who were seen by a dietitian during pregnancy had significantly lower rates being LGA compared to those who did not see a dietitian (9.4% vs 18.7%, p=0.017). The proportion of infants born LGA was significantly different according to the number of dietetic appointments attended where seeing a dietitian for two appointments compared to no appointments was associated with a significantly lower proportion of infants being born LGA (2.3% vs 18.7%, p=0.007). Those who saw a dietitian had lower rates of shoulder dystocia (0.9% vs 5.0%, p=0.031), and higher incidences of SGA (13.2% vs 5.3%, p=0.022) compared to those who did not see a dietitian during their GDM affected pregnancy. Dietetic input was not associated with any differences in incidence of neonatal hypoglycaemia, admission to the NICU or an Apgar score <7 after one or five minutes in women with GDM in this cohort.

Unadjusted and adjusted odds of neonatal outcomes according to frequency of dietetic input is shown in Table 5. In the unadjusted model, seeing a dietitian at all compared to not seeing a dietitian during pregnancy was associated with reduced odds of LGA, however this association was no longer significant in the adjusted model (Table 5). Similarly, when exploring differences in shoulder dystocia and SGA between women who saw a dietitian compared to those who did not, there were significant differences according to dietetic input, but these associations were no longer significant in the adjusted analyses. Odds ratios comparing three or more appointments to no appointments were unable to be calculated for several of the outcomes due to the low frequency of other birth outcomes.

Table 5. *Unadjusted and adjusted odds of neonatal outcomes according to frequency of dietetic input during GDM affected pregnancy.*

	Seen by a dietitian		**One**		**Two**		**Three or more**	
Neonatal outcomes	**OR (95% CI)**	**aOR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**
LGA	0.45 (0.24, 0.84)*	0.81 (0.38 1.70)	0.60 (0.31, 1.14)	1.0 (0.46, 2.15)	0.10 (0.01, 0.50)*	0.18 (0.01, 1.01)	0.23 (0.13, 1.18)	0.59 (0.03, 3.64)
SGA	2.70 (1.25, 6.51)*	1.81 (0.74, 4.84)	2.61 (1.14, 6.53)*	1.88 (0.73, 5.17)	2.80 (0.88, 8.55)	1.37 (0.33, 5.18)	3.13 (0.64, 12.05)	2.16 (0.38, 10.07)
Neonatal hypoglycaemia	1.25 (0.79, 2.00)	1.10 (0.62, 1.94)	1.34 (0.82, 2.22)	1.19 (0.66, 2.17)	1.30 (0.63, 2.68)	1.04 (0.44, 2.43)	0.59 (0.16, 1.80)	0.53 (0.13, 1.83)
Shoulder Dystocia [a]	0.17 (0.03, 0.70)*	0.23 (0.01, 2.03)	0.25 (0.04, 1.00)	0.30 (0.02, 2.55)	NA	NA	NA	NA
NICU admission	0.96 (0.48, 1.96)	0.89 (0.35, 2.28)	1.11 (0.52, 2.34)	1.02 (0.38, 2.73)	0.67 (0.15, 2.15)	0.50 (0.08, 2.23)	0.51 (0.03, 2.72)	0.86 (0.04, 6.53)
1-minute Apgar score <7	1.11 (0.55, 2.30)	0.95 (0.37, 2.53)	0.81 (0.35, 1.84)	0.63 (0.20, 1.87)	2.24 (0.84, 5.64)	2.21 (0.61, 7.52)	1.15 (0.17, 4.58)	1.35 (0.16, 7.56)
5-minute Apgar score <7	1.29 (0.38, 5.00)	0.69 (1.36, 3.5)	1.32 (0.34, 5.41)	0.61 (0.09, 3.53)	1.80 (0.24, 9.56)	1.61 (0.14, 12.80)	NA	NA

LGA, Large for Gestational Age; NICU, Neonatal Intensive Care Unit; SGA, Small for Gestational Age; OR, Odds Ratio; aOR, Adjusted Odds Ratio; Adjusted odds ratio calculated from adjusted logistic regression model (maternal age at delivery, maternal ethnicity, deprivation quintile, early pregnancy BMI, previous GDM, primigravida, early pregnancy HbA1c, diagnosis method; P<0.05 considered statistically significant. *P<0.05; **P<0.005; *NA,* odds ratio unable to be calculated from logistic regression due to frequency of 0; [a]Previous GDM removed from adjusted model due to VIF>10

As show in Figure 1, when women attended a single dietetic appointment during their pregnancy, the most common appointment type attended was individual, in-person (51%, n=71). As appointment frequency increased to two and three or more, telehealth consults become the most common treatment modality (two appointments: 55%, n=49; three or more appointments: 55%, n=36). Group appointments had the lowest overall attendance of any of the appointment types (9%, n=13; 15%, n=13; 15%, n=10; for one, two and three or more appointments, respectively).

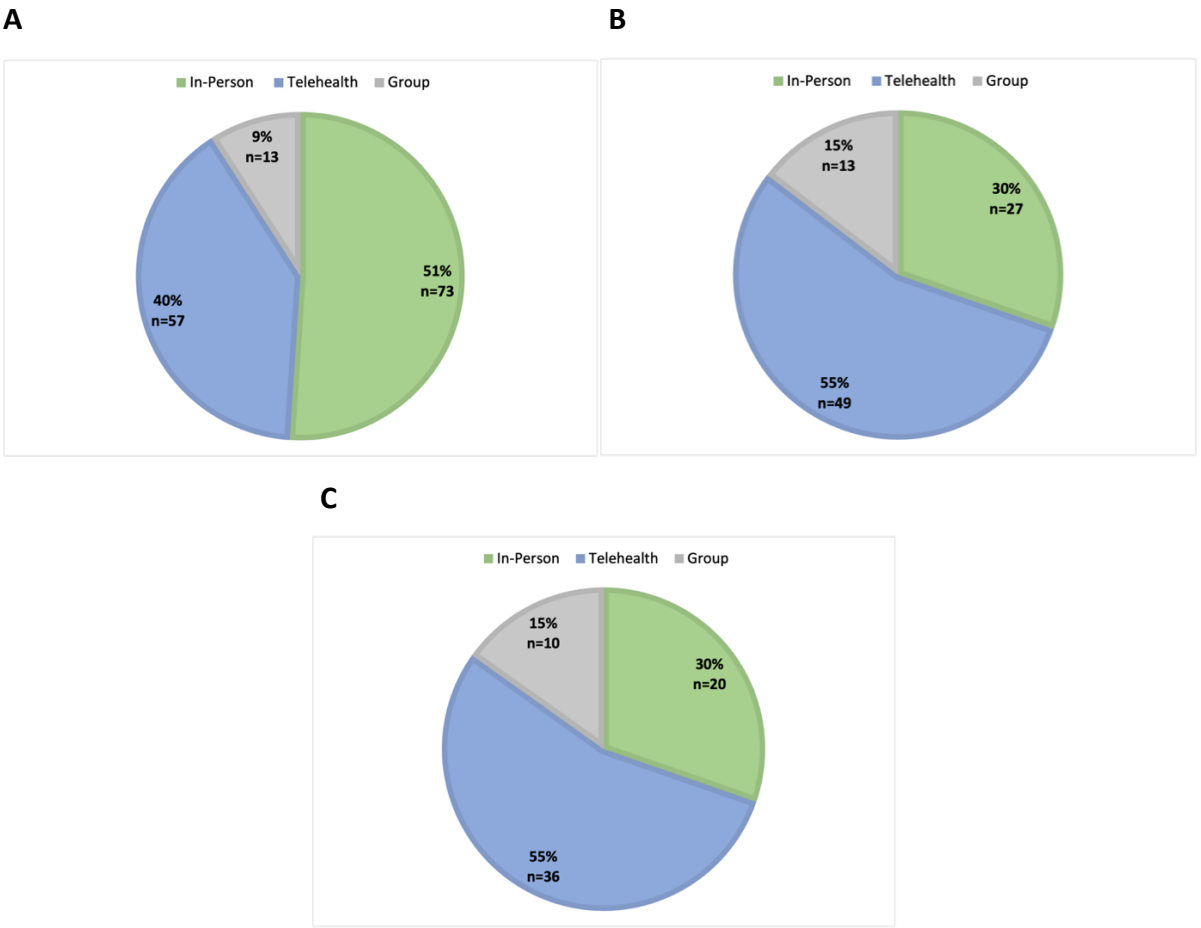

Figure 1*. Distribution of dietetic appointment type by those who attended* ***A****. One appointment,* ***B****. Two appointments,* ***C****. 3 or more appointments.*

Table 6. *Perinatal outcomes according to appointment type for women with GDM attending one appointment with a dietitian.*

		Appointment Type			
	Total (n= 143)	**In-person (n=73)**	**Telehealth (n=57)**	**Group (n=13)**	**P-value**
Maternal Outcomes					
Appropriate GWG					
Yes	40 (30.5)	30 (42.3)	10 (19.2) **	0 (0.0) **	**0.003**
No	91 (69.5)	41 (57.8)	42 (80.8)	8 (100.0)	
Commenced medication					
Yes	131 (92.3)	66 (90.4)	53 (93.0)	13 (100.0)	0.722
No	11 (7.7)	7 (9.6)	4 (7.0)	0 (0.0)	
Incidence of caesarean					
Yes	72 (50.3)	39 (53.4)	27 (47.4)	6 (46.0)	0.752
No	71 (49.7)	34 (46.6)	30 (52.6)	7 (53.9)	
Neonatal Outcomes					
LGA					
Yes	17 (12.4)	5 (7.1)	9 (16.4)	3 (25.0)	0.095
No	120 (87.6)	65 (92.9)	46 (81.8)	9 (75.0)	
SGA					
Yes	18 (13.1)	9 (12.9)	8 (14.6)	1 (8.3)	0.931
No	119 (86.9)	61 (87.1)	47 (85.5)	11 (91.7)	
Neonatal hypoglycaemia					
Yes	54 (42.9)	25 (37.9)	23 (46.0)	6 (60.0)	
No	72 (57.1)	41 (62.1)	27 (54.0)	4 (40.0)	
Shoulder dystocia					
Yes	1 (0.07)	0 (0.0)	0 (0.0)	1 (7.7)	0.091
No	142 (99.3)	73 (100.0)	57 (100.0)	12 (92.3)	

Admission to NICU					
Yes	15 (10.5)	8 (11.0)	6 (10.5)	1 (7.7)	1
No	128 (89.5)	65 (90.0)	51 (90.5)	12 (92.3)	
Apgar score after 1 minute					
≥7	9 (6.4)	5 (7.9)	4 (7.1)	0 (0.0)	1
<7	132 (141)	68 (93.1)	52 (92.9)	12 (100.0)	
Apgar score after 5 minutes					
≥7	4 (2.8)	2 (2.70)	1 (1.8)	1 (8.3)	0.395
<7	137 (97.2)	71 (97.3)	55 (98.2)	11 (91.7)	

GWG, Gestational Weight Gain; LGA, Large for Gestational Age; NICU, Neonatal Intensive Care Unit; SGA, Small for Gestational Age; P-value calculated using chi-squared or Fisher's exact test for all groups. *P<0.05 when compared with in-person in separate analysis; **P<0.005 when compared with in-person in separate analysis.

Table 6 shows perinatal outcomes by appointment type for those women who attended one appointment with a dietitian. Data on appointment type was not available for those who saw a dietitian at Te Whatu Ora sites other than Te Toka Tumai Auckland, therefore those who fell into this category were excluded from analyses relating to appointment type. A significantly lower proportion of women who attended a telehealth (19.2%, p=0.0125) or group appointment (0%, p=0.021) achieved appropriate GWG when compared with those who attended an in-person appointment (42.3%, p = 0.03). There were no other significant differences in primary or secondary perinatal outcomes according to dietitian appointment type.

Unadjusted and adjusted odds of perinatal outcomes in women with GDM according to dietitian appointment type are displayed in Table 7. Women who attended only a telehealth appointment compared to those attending only an in-person appointment, had a lower odds of achieving appropriate GWG during their pregnancy in both unadjusted and adjusted analyses (Table 7). Following adjusted analysis, infants born to mothers who attended a group teach only as opposed to an in-person appointment had significantly higher odds of being LGA (Table 7).

Table 7. Unadjusted and adjusted odds of perinatal outcomes for women who attended one dietetic appointment comparing telehealth and group teach appointments with in-person as reference.

	Telehealth		Group Teach	
Perinatal outcomes	**OR (95% CI)**	**aOR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**
Maternal outcomes				
Appropriate GWG	0.33 (0.14, 0.73) *	0.22 (0.08, 0.58) **	NA	NA
Commenced Medication[b]	1.41 (0.40, 5.60)	1.10 (0.14, 10.3)	NA	NA
C-Section	0.79 (0.39, 1.57)	0.75 (0.33, 1.67)	0.75 (0.22, 2.46)	0.77 (0.18, 3.18)
Neonatal outcomes				
LGA	2.54 (0.82, 8.74)	2.73 (0.66, 12.84)	4.33 (0.79, 21.03)	9.01 (1.05, 81.0) *
SGA	1.15 (0.41, 3.24)	1.14 (0.31, 4.17)	0.62 (0.03, 3.80)	0.99 (0.03, 1.17)
Neonatal Hypoglycaemia	1.40 (0.66, 2.96)	1.94 (0.73, 5.43)	2.46 (0.64, 10.44)	4.49 (0.60, 42.14)
Shoulder Dystocia	NA	NA	NA	NA
NICU[c]	0.95 (0.30, 2.92)	0.42 (0.7, 2.16)	0.68 (0.04, 4.21)	0.05 (0.0004, 0.98)
Apgar score <7 after 1 minute [d]	1.05 (0.25, 4.14)	0.91 (0.08, 7.45)	NA	NA
Apgar score <7 after 5 minutes	0.65 (0.03, 6.9)	NA	3.23 (0.14, 36.57)	NA

GWG, Gestational Weight Gain; LGA, Large for Gestational Age; NICU, Neonatal Intensive Care Unit; SGA, Small for Gestational Age; OR, Odds Ratio, aOR; Adjusted Odds Ratio; Adjusted odds ratio calculated from adjusted logistic regression model (maternal age at delivery, maternal ethnicity, deprivation quintile, early pregnancy BMI, previous GDM, primigravida, early pregnancy HbA1c, diagnosis method. *NA,* odds ratio unable to be calculated from logistic regression due to frequency of 0. *P<0.05; **P<0.005. [b]Diagnosis method removed from adjusted model due to VIF >10; [c]Maternal ethnicity removed from adjusted model due to VIF >10, [d]Maternal ethnicity and deprivation quintile removed from adjusted model due to VIF >10.

Chapter 4. Discussion

This study evaluated the level of dietetic input received by women with a diagnosis of GDM who gave birth at Te Toka Tumai Auckland between 1st July 2022 and 31st December 2022. It also evaluated whether the mode or frequency of dietetic input influenced maternal and neonatal outcomes related to GDM. This study found that seeing a dietitian during pregnancy was associated with gestational weight gain within recommended ranges, and in-person, individual MNT to be associated with higher odds of gestational weight gain within recommended ranges, and lower odds of infants born large-for-gestational-age when compared with telephone consults and group teach appointments.

4.1 Dietetic input and perinatal outcomes

As highlighted in the literature on GDM, MNT is regarded as the 'cornerstone' of treatment, (Moreno-Castilla et al., 2016). Guidelines for the management of GDM in Aotearoa recommend "*weight and lifestyle advice [is] ideally provided by a dietitian*" (Ministry of Health, 2014b). Within our study cohort, only 58.2% of women with a diagnosis of GDM received input from a dietitian, as recommended by the Ministry of Health (Ministry of Health, 2014b). Comparatively, the proportion of women with a diagnosis of GDM seen by a dietitian in this study is lower than other New Zealand-based studies (Lawrence et al., 2017; Mustafa et al., 2022). Mustafa et al. (2022) reported 85.9% of women in their study population were seen by a dietitian during their GDM-affected pregnancy (Mustafa et al., 2022). Lawrence et al.'s (2017) cross-sectional survey of dietitians showed that 73% of dietitians reported that all women with a GDM diagnosis were referred to a dietitian. The two studies discussed did include nation-wide samples of women and dietitians, which is a key difference compared with the Te Toka Tumai Auckland cohort investigated in this study. Data collection for both studies also took place prior to the COVID-19 pandemic and associated restrictions, while 2022 cohort for this study were being treated for GDM during or soon after pandemic restrictions in Auckland (New Zealand Government, 2022a, 2022b), which may contribute to lower attendance rates.

Maintaining appropriate gestational weight gain is a core goal in the dietetic treatment of women with GDM (Duarte-Gardea et al., 2018), however, in our study, only 22.7% of women achieved weight gain within the IOM recommendations. The adjusted model of analysis (controlling for maternal age at delivery, maternal ethnicity, deprivation quintile, early pregnancy BMI, GDM in a previous pregnancy, primigravida, early pregnancy HbA1c and method of GDM diagnosis) showed that women who saw a dietitian during their GDM affected pregnancy were twice as likely to achieve gestational weight gain within recommendations compared to those who did not see a dietitian. In the survey of dietetic practice by Lawrence et al., 96% of dietitians surveyed reported discussing gestational weight gain with women during their GDM-affected pregnancy (Lawrence et al., 2017) which may suggest dietetic input has a significant impact on gestational weight gain for women with GDM.

Significant risks are associated with both excess and insufficient gestational weight gain during a GDM affected pregnancy. Excess weight gain in pregnancy has been associated with increased rates of pre-eclampsia (Yogev et al., 2004), neonatal hypoglycaemia (Arimitsu et al., 2023), higher infant birthweight (Berggren et al., 2014; Galjaard et al., 2013), and higher child adiposity at three years of age (Oken et al., 2007). Although IOM weight gain recommendations are lower for women classed as obese or overweight, weight gain below these recommendations (or weight loss) is associated with increased risk of SGA (Catalano, 2014). It has also been shown to approximately double the odds of infant mortality even when adjusted for gestational age at birth and infant birthweight (Davis & Hofferth, 2012). Inappropriate gestational weight gain at either end of the spectrum is associated with increased risk of pre-term birth (Rasmussen & Yaktine, 2009). Our finding that being seen by a dietitian increases the odds of appropriate weight gain demonstrates the importance of incorporating dietetic input in the model of care for women with GDM.

Similar to the findings of Mustafa et al. (2022) our study did not find an association between visiting a dietitian and incidence of birth via caesarean, neonatal hypoglycaemia, or shoulder dystocia (Mustafa et al., 2022). Mustafa et. al did show that seeing a dietitian was associated with reduced odds of LGA infants however this odds ratio was not adjusted for maternal socio-demographic or health characteristics. The unadjusted model in our study had similar

results (OR = 0.45, Cl = 0.24, 0.84), but was no longer significant after adjusting for potential confounders. While dietetic input was associated with lower median infant birthweight in our study, this may not have clinical significance as the odds of LGA and SGA were not significant in the adjusted model of analysis.

4.2 Frequency of dietetic input and perinatal outcomes

The Academy of Nutrition and Dietetics and the Queensland Clinical guidelines recommend at least three dietetic appointments during pregnancy for women diagnosed with GDM (Duarte-Gardea et al., 2018; Queensland Clinical Guidelines, 2022), as this was associated with a reduced need for pharmaceutical management of GDM in a randomised control trial of 215 women with GDM (Reader et al., 2006). However, only 5.3% of women in our study population saw a dietitian three or more times during pregnancy. Twenty eight percent of Aotearoa dietitians surveyed in 2015 reported seeing women an average of three or more times during their pregnancy (Lawrence et al., 2017), but again, this study had a wider regional sample and took place before the COVID-19 pandemic. Reasons for such a low proportion of women attending the three dietetic appointments recommended may include capacity restrictions in the service, resulting in a need to prioritise treatment to those who need it most. This may include women with poorer control of their BGLs, diet and weight gain, while those who are managing well may be discharged.

When looking at appointment frequency, those who attended one appointment had higher odds of achieving appropriate weight gain compared to those who attended none. However, there did not appear to be a relationship with appropriate weight gain as frequency of appointments increased. Initially, it may be expected that those seeing a dietitian more often may gain weight more appropriately, as with more appointments, more monitoring and evaluation or 'tailoring' of dietetic care can be achieved, but when observing the results of this study this was not the case. However, frequency of dietetic input largely relies on a dietitian's clinical judgement, therefore those seen for one appointment may be identified by the practicing dietitian to be tracking appropriately in terms of weight gain, and subsequently discharged following dietary assessment and intervention. Those finding it more difficult to gain sufficient weight or gaining excess weight may be invited to further follow-up

appointments in order to provide support with achieving appropriate weight gain. Similarly, Shi et al. also found that MNT can influence gestational weight gain during pregnancy. Shi et al. suggested that that those who do not receive MNT initially gain weight at an insufficient rate immediately following GDM diagnosis due to excess energy restriction and lack of appropriate guidance. They then rebound and gain significantly more weight in total during their pregnancy than those who received MNT (Shi et al., 2016). Robertson and Ladlow (2018) found that women with a pre-pregnancy BMI categorised as obese gained significantly less weight than their previous pregnancies following dietetic intervention (3.6 ± 5.4 kg vs 4.3 ± 11.2 kg), and those who attended three appointments gained significantly less weight than those who attended one or two appointments (Robertson & Ladlow, 2018). However, it is worth considering that the mean weight gain of 3.6kg in the group of women who had previously been pregnant is below the IOM guidelines for gestational weight gain for obese women (Rasmussen & Yaktine, 2009). In our study, seeing a dietitian three or more times was associated with significantly lower gestational weight gain than those who did not see a dietitian during pregnancy (6.34 vs 10.79 kg, $p<0.001$) however, this was not reflected in an increase in appropriate weight gain in the adjusted model. This may suggest that excess weight gain may have been replaced by insufficient weight gain.

It is recommended that women with GDM begin pharmacological treatment with insulin or metformin if they are no longer able to appropriately manage their blood glucose levels through the 'first-line treatments' of lifestyle and diet modification alone (Duarte-Gardea et al., 2018; Ministry of Health, 2014b). Therefore, it could be hypothesised that those receiving more dietetic input during pregnancy may have lower rates of pharmaceutical management of GDM if they are receiving tailored support to manage their blood glucose levels, but this was not observed in our study. In our study, those who saw a dietitian during pregnancy had markedly higher odds of being prescribed diabetes medication than those who did not see a dietitian. Women who were seen by a dietitian a total of once were also more likely to be on diabetes medication than those who received no dietetic input. All women who saw a dietitian three or more times were prescribed diabetes medication. A variation in the literature has been observed on the relationship between dietetic input and commencing medication. With evidence of both a negative relationship (Reader et al., 2006; Shi et al., 2016), and a positive relationship (Meloncelli et al., 2020; Mustafa et al., 2022) being

observed between the two. These contradictory findings may be due to the confounding factor that women with blood glucose levels that are more difficult to control or those requiring medication may need greater support and may be more likely to be referred to a dietitian and/or seen more frequently whereas in other cases, greater dietetic input by a dietitian may lead to reduced requirement for pharmacological management.

Our study showed no significant relationship between the frequency of dietetic input and incidence of c-section, LGA, SGA, neonatal hypoglycaemia, and shoulder dystocia. Current literature demonstrates significant inconsistencies in the relationship between dietetic care and these perinatal outcomes related to GDM. Most studies present conflicting evidence on one or more perinatal outcomes (Crowther et al., 2005; Landon et al., 2009; Perichart-Perera et al., 2009; Shi et al., 2016). A key challenge when placing our study in the context of the wider literature available on the effects of MNT on perinatal outcomes for women with GDM is the heterogeneity of interventions provided between trials. For example, women in Perichart-Perera's (2009) study received an average of 7.4 individual MNT appointments, whereas both Crowther et al.'s (2005) and Landon et al.'s (2009) studies investigate a more holistic approach to the treatment of GDM including individualised dietetic advice, blood glucose self-monitoring and insulin therapy, with the number of MNT appointments attended being undefined.

4.3 Type of dietetic appointment attended and perinatal outcomes

In our study, those who saw a dietitian via telehealth appointment had significantly lower odds of achieving appropriate gestational weight gain compared to those who saw a dietitian in-person. In Reader et al's (2006) randomised control trial validating a set of nutrition practice guidelines, a minimum of three appointments with a dietitian was required. However, only the initial appointment was required to be in-person, and follow-up appointments could also be via telehealth (phone call or fax)(Reader et al., 2006). This recommendation holds true when observing the study population, as seen in Fig. 1, where in person appointments were the most common modality when women attended a single dietitian visit during their pregnancy, however for both two and three or more appointments, telehealth became the primary method of MNT delivery.

The use and place of telehealth for dietetic consultation was explored in a cross-sectional survey of 2016 registered dietitians during the COVID-19 pandemic, who, while acknowledging benefits of telehealth nutrition care such as improved scheduling flexibility and reduced transport cost for clients, reported that they were not able to conduct some typical assessment or monitoring/evaluation activities, and experienced difficulty establishing rapport via telehealth (Rozga et al., 2021). Women involved in a qualitative study investigating their experiences of managing GDM in Aotearoa commented on the importance of mutual trust and collaborative goal setting with health professionals, (Lawrence et al., 2021) so identifying key ways to strengthen this trust is paramount when optimising treatment guidelines. Rozga et al.'s (2021) survey also identified challenges for dietitians assessing anthropometric measures, which is an important consideration as the key outcome measure affected by telehealth consults was gestational weight gain. Perhaps as dietitians were limited in their ability to weigh patients during telehealth consults, focussing on weight as a metric was less common than in-person appointments. An analysis of outpatient appointment attendance in the British National Health Service during the COVID-19 pandemic showed that initial appointment attendance rates were significantly higher for in-person appointments than 'remote' (telehealth) appointments (Kerr et al., 2023). As society adapts to the use of virtual technologies, access and acceptability of these technologies may see a change in the delivery of MNT. Perhaps, in future, causing these barriers to effective communication and nutrition consult delivery will be mitigated.

Evidence from the HAPO study has shown blood glucose levels to be predictive of high birthweight (Metzger et al., 2008). Infants born large-for-gestational-age are known to be at increased risk of birth via emergency and elective c-section, shoulder dystocia, Apgar score of <7 and admission to NICU/SCBU (Special Care Babies Unit) (Chen et al., 2023; Jolly et al., 2003; Youssefzadeh et al., 2023). In our study, women who attended one group appointment compared to one individual in-person appointment had significantly higher odds of giving birth to a LGA infant. Highlighting that individualised dietetic care could affect these outcomes by reducing the risk of LGA is imperative for the development of future clinical practice guidelines for the treatment of GDM. While group appointments can be valuable in delivering nutrition education efficiently to a larger group of people, they allow for a less

tailored approach focusing on a woman's individual blood glucose patterns, existing diet, and social considerations.

The low frequency of attendance to group appointments restricted the ability to determine any other relationships between group appointment attendance and some perinatal outcomes. When Barnes et al. (2018) investigated the effects of group nutrition education on women with GDM, they did not find increased incidence of LGA infants in women who had attended a group appointment but did find an increased risk of requiring insulin treatment (Barnes et al., 2018). Although an adjusted odds ratio was unable to be calculated, our study showed that all of the women who attended a group appointment as their only form of dietetic input also required medication to treat their GDM. Attendance at group appointments in the study by Barnes et al. (2018) was lower than that of individual appointments.

Data from a Canadian longitudinal cohort study of 91,382 children found that those who were LGA as infants were twice as likely as average-for-gestational-age infants to be overweight or obese when aged four to six years (Kaul et al., 2019). This effect was amplified when mothers had GDM during their pregnancy, increasing the odds ratio to 2.79 (Kaul et al., 2019). If in-person, individual dietetic input during pregnancy can reduce the incidence of LGA, this is just one of many strategies that can be used to manage childhood obesity rates in Aotearoa, where prevention from a young age has been identified as a key strategy (Chiavaroli et al., 2019).

A challenge in comparing findings from our study to the wider body of literature is that in the Te Toka Tumai Auckland GDM clinic setting, a telehealth consult simply refers to a typical appointment with a dietitian, except that it is carried out via phone call rather than the women coming to a clinic. An issue arises in evaluating the effectiveness of telehealth MNT care for GDM in the literature, as telehealth often refers to web or app-based treatment, 24-hour response via text, and real-time monitoring and feedback (Eberle & Stichling, 2021; Rasekaba et al., 2015; Rasekaba et al., 2018; Xie et al., 2020). Most of the identified literature features a 'no intervention' control group, rather than comparing the effects of telehealth

versus in-person nutrition care on perinatal outcomes related to GDM. While women with GDM at Te Whatu Ora often have access to text or email feedback on their blood glucose levels from their diabetes nurse or midwife, this does not extend to dietetic care, so much of the available literature on telehealth interventions is not applicable to our target population.

As discussed, seeing a dietitian in-person compared to in a group or telehealth setting was associated with appropriate gestational weight gain and reduced incidence of LGA. What can be taken from these results is the need for in-person individual appointments to be prioritised, encouraged, and invested in for improved perinatal outcomes. A treatment model that prioritised in-person, individual dietetic care, but still provided options for group and telehealth appointments to allowed for flexibility when needed could be a way to capture the benefits of all treatment modalities to both provider and patients, as has previously been trialled (Meloncelli et al., 2020; Reader et al., 2006).

4.4 Strengths and limitations

Results from this study are a representation of the practices and outcomes of care for women with GDM at Te Toka Tumai Auckland in 2022. An effort was made, where possible, to include the full sample population in the analysis. Whilst including only women who were diagnosed via 2hr OGTT may have been more in-line with other studies in the literature, extending our inclusion criteria to all methods used to diagnose GDM in practice at Te Toka Tumai Auckland provides more meaningful 'real world' results. This also provided a more in-depth picture of dietetic treatment of GDM at Te Toka Tumai Auckland as these are all included in the National Women's Health dataset reporting on prevalence of GDM and follow similar treatment pathways (National Women's Health, 2022). Crowther et al. (2005) highlights the value in treating women with a lower diagnostic threshold for GDM, demonstrating that these women should be included in the research and treatment of GDM (Crowther et al., 2005). This also means that findings from this study may be taken into consideration when looking at the Diabetes in Pregnancy pathways as a whole, rather than only being extrapolated to women diagnosed via 2hr OGTT. Given the LGA/BGL pathway of diagnosis is more typically used to diagnose GDM later in pregnancy (National Women's Health, 2022), it is possible that those diagnosed through this pathway were less likely to be referred to a dietitian. This was evident

in our results where a greater proportion of women who were not seen by a dietitian were diagnosed via this pathway. Dietetic input may also be less likely to affect their birth outcomes at this late diagnosis than if it were received earlier in the pregnancy. This is a key justification for GDM diagnosis method to be included in the adjusted model, as this could be a confounding factor for outcomes such as LGA.

Seeing a dietitian during pregnancy was associated with lower median gestational weight gain, however this does not provide sufficient insight as to whether this is a positive change for this population. For this reason, a key strength of our study is using 'appropriate gestational weight gain' as an outcome variable, in order to ensure achieving appropriate weight gain rather than 'limiting' weight gain as the goal of care for women with GDM. Using IOM gestational weight gain guidelines as a metric also acknowledges the individualised nature of weight gain targets for women during their pregnancy, and the fact that mean weight gain during pregnancy can be arbitrary without being positioned in relation to a women's pre-pregnancy weight.

A significant challenge in identifying any relationships between appointment type and perinatal outcomes was the fact that many women attended more than one type of appointment. For this reason, relationships between type of appointment and perinatal outcomes were assessed for women who attended one appointment only. This allowed for clear delineation between appointment type. Information on the number and type of dietetic appointments attended was only able to be collected through information systems associated with Te Whatu Ora and Te Toka Tumai Auckland. If a women saw a dietitian through private practice or associated with her primary care provider during pregnancy, this was not captured in our data collection, therefor the true number of dietetic appointments attended during pregnancy by women with GDM may be higher than what is reported in this study.

The potential for human error exists within this study, as a large number of the variables included rely on accurate data entry of health professionals into the clinical software systems at the time of recording. A challenge of the manual data collection process was difficulty finding records of women attending the group teach appointments. Booking dates were identified in the outpatient appointments tab of Regional Clinical Portal, and clinical notes

were searched for keyword ‘group’ to identify invitation or attendance to the group teach programme. As full clinical notes are not provided following the group teach session (as opposed to individual sessions), it is possible that some women attended the group teach programme without it being clinically documented, thus leaving the potential for underreporting of the true number of women seen by a dietitian in the group setting.

Initially, a goal for this research was to stratify results by ethnicity, considering incidence of GDM development has been shown to vary significantly between ethnic groups in Aotearoa (Lawrence et al., 2020), as well as specifically looking at perinatal outcomes for wāhine Māori with GDM. The small sample size of Māori women (n=23) within this cohort meant that we were unable to discuss ethnicity-specific outcomes or be responsive to Māori as it does not provide equal explanatory power (Te Rōpū Rangahau Hauora a Eru Pōmare, 2002). In this instance we were unable to conduct a thorough analysis of GDM related health outcomes and dietetic input specifically in this population. We were hesitant to include numeric data on Māori health outcomes for such a small sample size without qualitative considerations including the Māori voice on access to and acceptance of dietetic intervention. This provides an opportunity into further qualitative research into this, investigating wāhine Māori experience with GDM. In the National Women’s Health Annual Clinical Report 2022, concerns were raised that cases of GDM are being missed among wāhine Māori and National Women’s Health has ongoing goals to improve access to care and engagement with services (National Women’s Health, 2022). This concern is substantiated by Chepulis et al. (2020) who, in a retrospective review of 807 clinical records, found that wāhine Māori were being screened for GDM later in their pregnancy, and were less likely to be screened as per the Ministry of Health guidelines than their non-Māori counterparts (Chepulis et al., 2020).

4.5 Opportunities for future research

This study looked at the effect of dietetic input on perinatal outcomes – those relating directly to pregnancy and birth. Further research exploring how dietetic input may impact medium to long-term outcomes relating to GDM such as development of T2DM, post-partum weight loss, infant bodyweight centile at two years and child development would be valuable.

The observational nature of our retrospective cohort study means it was difficult to detangle the relationship between the optimal number of appointments attended to improve perinatal outcomes. Women with GDM at Te Toka Tumai Auckland were followed up on an 'as required' basis, so those with higher appointment attendance may have simply required greater support for management of their GDM. In the cross-sectional survey of dietitians in Aotearoa treating women with GDM by Lawrence et al. (2017), key factors affecting frequency of dietetic input included dietitians' clinical judgement and glycaemic control (Lawrence et al., 2017). Given there are multiple factors involved in the decision to discharge or follow-up a patient at the end of their appointment, the true impact of frequency of dietetic input would best be investigated through a randomised control trial looking at the same explanatory and outcomes variables included in this study. This could eliminate any confounding factors between rationale for appointment frequency and perinatal outcomes. However, given ethical concerns with not providing a clinically indicated level of treatment to women with GDM who need it, such a trial would likely need implementation of practice guidelines stating a minimum level of dietetic input.

As discussed, representation of wāhine Māori in this cohort was too low to independently assess the level of care provided to them during their GDM affected pregnancy. There is potential for a similar study to ours to be conducted looking more broadly at the level of dietetic care provided to Māori women with GDM across Aotearoa and comparing this information with national and international guidelines.

While quantitative research and clear numerical data on inputs and outcomes relating to GDM provide significant value when it comes to designing and modifying models of care, there is only so much depth of information that can be found within the scope of quantitative research. Further exploring women's perceptions and experiences of the values and burdens of dietetic care during their pregnancy, and their perspective on engagement with dietetic services could be incredibly valuable. Qualitative studies have explored women's experiences with their diet and exercise during pregnancy and following GDM diagnosis (Paterson et al., 2016; Smyth et al., 2023). Smyth et al. (2023) identified that access to a dietitian was a key barrier to care for a women with GDM (Smyth et al., 2023). Investigating women's relationship with dietetic care specifically, how the advice was tailored to them and its ability

to be implemented into their lifestyle could build on the current literature. This could be supplemented by qualitative research talking to dietitians about the challenges and benefits of different modes of MNT delivery and how they feel different modalities such as telephone consults or group teach programmes provide a platform for them to deliver high-quality care. North et al. (2022) identified that health professionals (including dietitians) in Aotearoa saw telehealth as an enabler of GDM service provision, and identified the current need for group nutrition education in response to capacity constraints (North et al., 2022). Delving deeper into dietitians' experiences of the quality of nutrition intervention delivered through each appointment type may prove valuable.

4.6 Conclusion

In this study, just over half of pregnant women with a diagnosis of GDM at Te Toka Tumai Auckland received diet and lifestyle advice from a dietitian as recommended by the Ministry of Health. Those who did receive dietetic input were more likely to gain weight according to recommendations, which is known to have beneficial follow-on effects for both mother and infant. Furthermore, women who saw a dietitian in an individual, in-person setting as opposed to in a group setting were less likely to give birth to a LGA infant. In-person appointments rather than group or telehealth appointments, had favourable outcomes in terms of gestational weight gain and infant birthweight. These findings highlight dietitians' unique skillset in achieving patient outcomes through building rapport and delivering tailored interventions. Further research exploring whether there is an optimal minimum threshold for the number of dietetic appointments on perinatal outcomes is required.

This study has shown that seeing a dietitian during a GDM-affected pregnancy at Te Toka Tumai Auckland, and specifically in-person, may be associated with improved perinatal outcomes for both mother and baby. All women with a diagnosis of GDM should be seen by a registered dietitian to promote optimal outcomes, and, where possible, individualised face-to-face care should be prioritised and resourced accordingly.

Appendices

Appendix A. AHREC Approval

AUCKLAND HEALTH RESEARCH ETHICS COMMITTEE (AHREC)

08/12/2022

Dr Robyn Lawrence

Nutrition

Re: Application for Ethics Approval (Our Ref. AH24942): Approved with Comment

The Committee considered the application for ethics approval for your study entitled "**Dietetic input for women with gestational diabetes and perinatal outcomes**". We are pleased to inform you that ethics approval has been granted with the following comment(s) or required minor changes:

1. The Committee suggests that applicants consider the importance of ongoing Māori consultation and engagement for this study.

The expiry date for this approval is **08/12/2025**.

Locality approval: Before starting your research, ensure that all the required locality approvals have been obtained. If one or more DHBs will be a locality, please contact their Research Office(s) to determine the locality approval requirements of the DHB(s).

Final report: In order that up-to-date records are maintained, you must notify the Committee once your project is completed and submit a final report.

Amendments to the approved project: Should you need to make any changes to the approved project, please follow the steps below:

- Send a request to the AHREC Administrators to unlock the application form (using the Correspondence tab in Ethics RM).
- Make all changes to the relevant sections of the application form and attach revised documents (as appropriate).
- Change the Application Type to "Amendment request" in Section L.
- Add a summary of the changes requested in the text box.
- Submit the amendment request (PI/Supervisors only to submit the form).

If the project changes significantly, you are required to submit a new application.

Funded projects: If you received funding for this project, please provide this approval letter to your local Faculty Research Project Coordinator (RPC) or Research Project Manager (RPM) so that the approval can be notified via a Service Request to the Research Operations Centre (ROC) for activation of the grant.

The Chair and the members of AHREC would be happy to discuss general matters relating to ethics approvals. If you wish to do so, please contact the AHREC Ethics Administrators at ahrec@auckland.ac.nz in the first instance.

Additional information:

- Do not forget to fill in the 'approval wording' on the PISs, CFs and/or advertisements, using the date of this approval and the reference number, before you use the documents or send them out to your participants.

All communications with the AHREC regarding this application should indicate this reference number: **AH24942**.

AHREC Administrators

Auckland Health Research Ethics Committee

Appendix B. Te Toka Tumai Auckland locality approval

4 April 2023

Te Whatu Ora
Health New Zealand

Dr Robyn Lawrence
Clinical Dietitan
University of Auckland
Auckland , 1023

Kia ora / Dear Robyn Lawrence,

Locality approval for research – Te Toka Tumai Auckland

The Research Review Committee Te Toka Tumai Auckland (RRC) would like to thank you for the opportunity to review your study and has given approval for your research project.

A+ 9722 (AH24942) Dietetic input in women with gestational diabetes and perinatal outcomes: A retrospective cohort study

Your Institutional approval is dependent on the Research Office having up-to-date information and documentation relating to your research and being kept informed of any changes to your study. It is your responsibility to ensure you have kept Ethics and the Research Office up to date and have the appropriate approvals. Te Toka Tumai Auckland locality approval may be withdrawn for your study if you do not keep the Research Office informed of the following:

- Any communication from Ethics Committees, including confirmation of annual ethics renewal
- Any amendment to study documentation
- Study completion, suspension or cancellation

More detailed information is included on the following pages. If you have any questions please do not hesitate to contact the Research Office.

Ngā mihi/Yours sincerely,

Mary-Anne Woodnorth
Manager, Research Office, Auckland City Hospital, on behalf of RRC
Te Toka Tumai Auckland

TeWhatuOra.govt.nz
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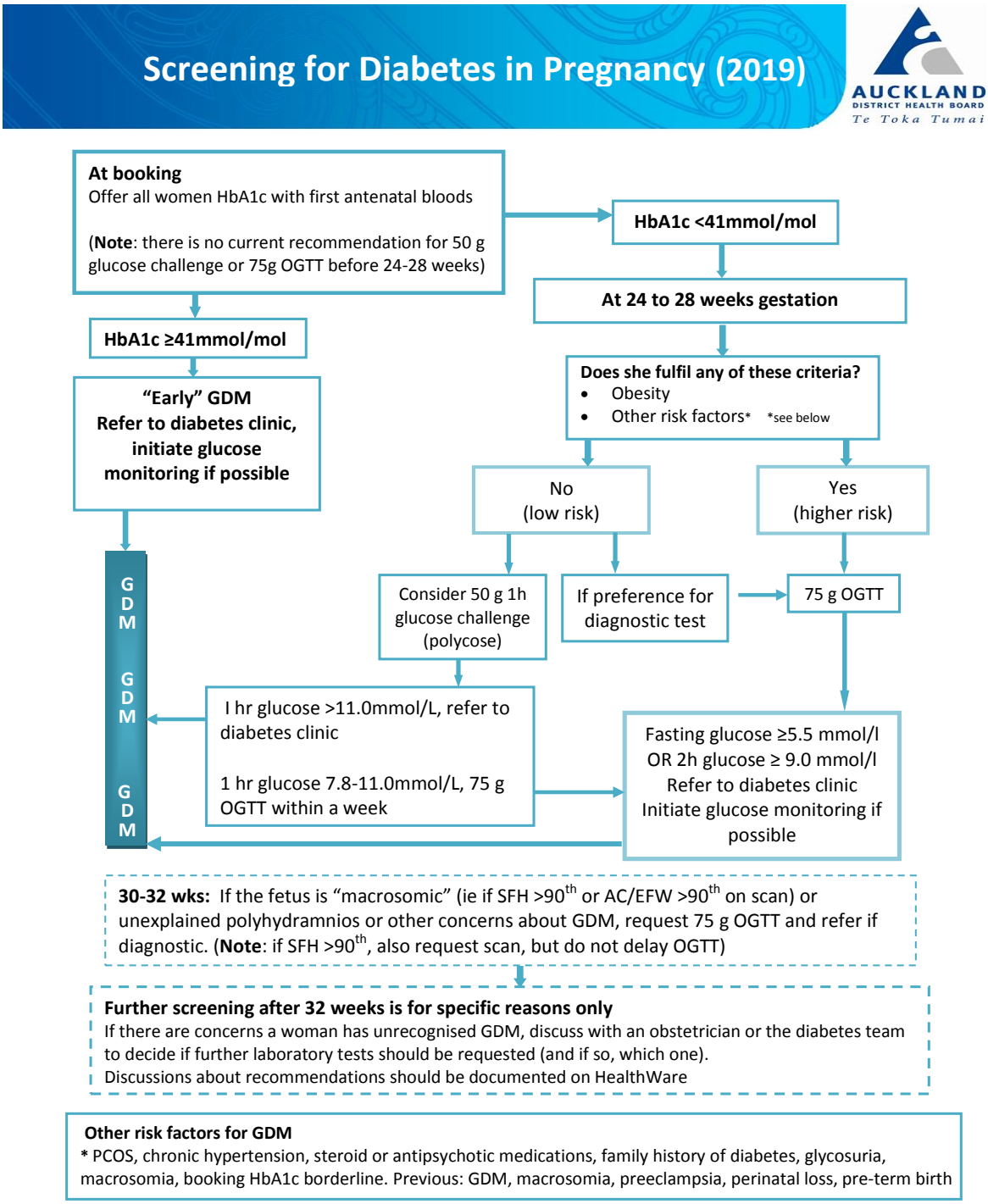
Waea pūkoro: +64 9 307 4949 ext 23854

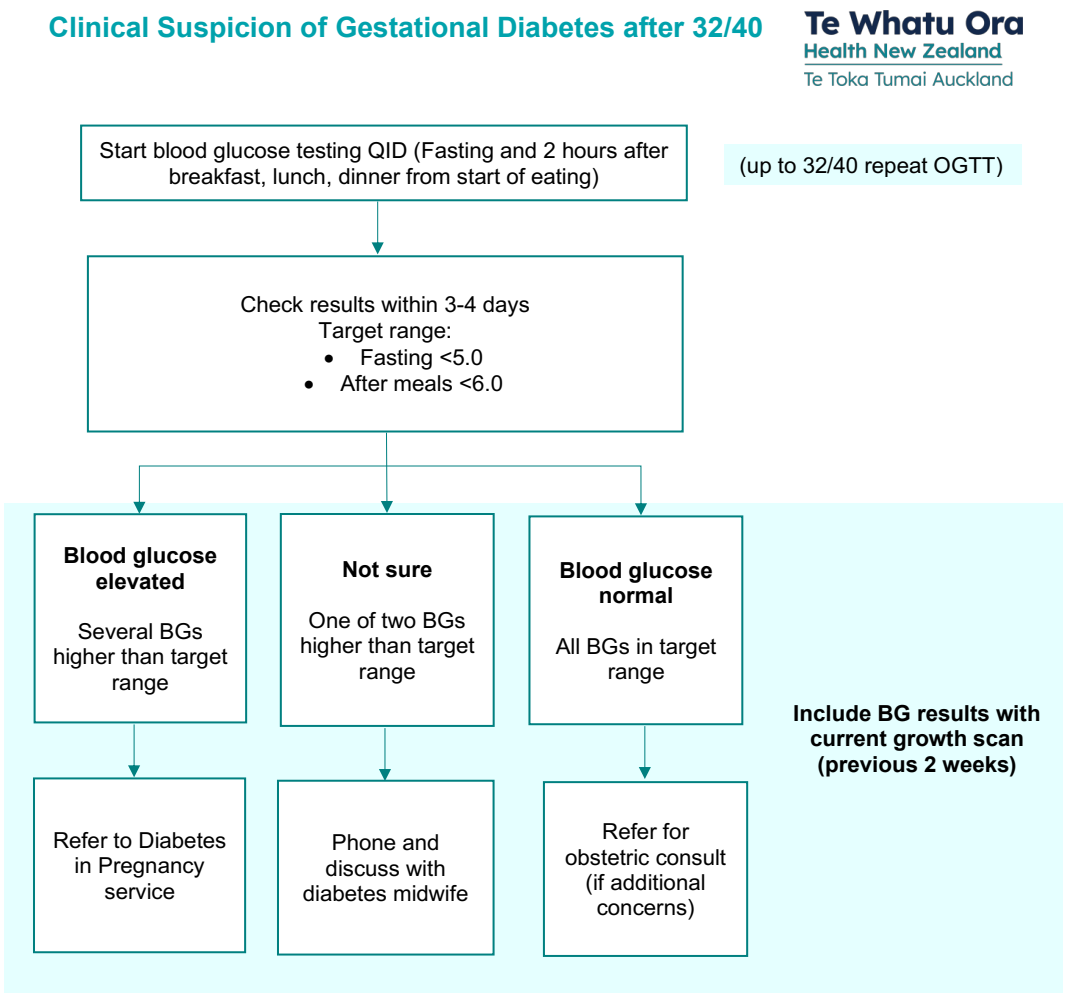
Te Kāwanatanga o Aotearoa
New Zealand Government

Appendix C. Te Toka Tumai Screening for Diabetes in Pregnancy Guidelines



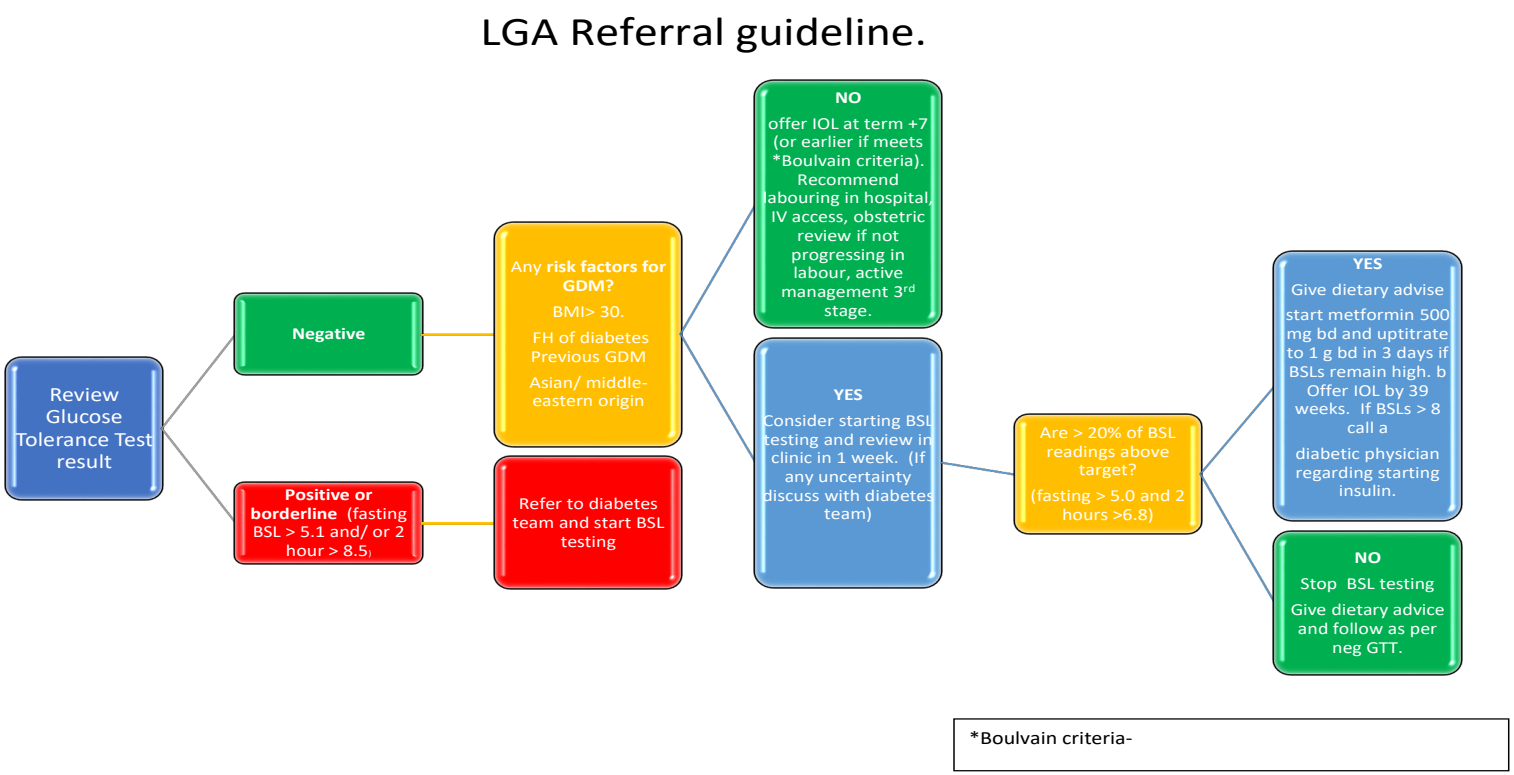
(National Women's Health, 2019)

Appendix D. Te Toka Tumai Clinical Suspicion of GDM after 32 weeks Guidelines



(National Women's Health, 2020)

Appendix E. Te Toka Tumai LGA referral guidelines for GDM



(National Women's Health, 2023)

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