INVESTIGATION OF THE UNDERLYING, MODIFIABLE AND NON-MODIFIABLE RISK FACTORS FOR GESTATIONAL DIABETES AMONG WOMEN LIVING IN CAPE TOWN

By

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DECLARATION

I, ……Elzie Chebet Koech………., hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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ABSTRACT

Gestational Diabetes Mellitus has adverse effects in pregnancy that affects both the mother and infant. These complications include preeclampsia, macrosomia, preterm birth and risk of developing Type 2 diabetes later in life. Understanding the risk factors for GDM is important in order to come up with intervention programs.

This study aimed to determine the underlying modifiable, non-modifiable and intermediate risk factors of GDM for women living in Cape Town South Africa. We also compared lifestyle factors between women after diagnosis of GDM and women without GDM.

Methods: We conducted a case-control study among women living in Cape Town. Cases were defined as women diagnosed with GDM recruited at Groote Schuur Hospital while controls were women without GDM recruited from Vanguard clinic. Questionnaires and medical record review were used to collect data. The association between GDM and both risk factors and lifestyle variables was analysed using multivariable logistic regressions, with GDM as a binary outcome variable.

Results: A total of 167 cases and 199 controls were included in the study. The mean age of cases was 32.5 years (28.0-37.0) and the mean age of controls was 25 years (22.0-31.0). In adjusted analyses, the risk factors for GDM were; family history of diabetes mellitus (OR 3.10, 95% CI 1.45-6.61, p =003), (MUAC) (OR 1.17, 95% CI 1.04-1.31, p =0.008) and stillbirth (OR 11.61, 95% CI 1.04-129.90, p =0.047), and BMI (OR 1.11, 95% CI 1.05-1.17, p <0.001). The optimum MUAC cut-off point for predicting GDM was 30.1cm, with a sensitivity of 84% and specificity of 59%. The BMI cut-off point for predicting GDM was 32.4 kg/m^2, with a sensitivity of 77% and a specificity of 68%.

For lifestyle factors, cases were more likely to eat foods with a lower fat content (OR 1.06, 95% CI 1.02-1.10, p=0.003) and high fibre carbohydrates (OR 1.07, 95% CI 1.01-1.12, p=0.011). However, they were less likely to eat added sugar (OR 0.94, 95% CI 0.90-0.98, p=0.001) and energy-dense snacks (OR 0.91, 95% CI 0.91-0.99, p=0.014). Additionally, women with GDM had more controlled eating compared to their counterparts (OR 0.118, 95% CI 0.02-0.73, P=0.022).

In conclusion, high MUAC, family history of diabetes mellitus and still birth are associated with an increased risk of GDM. Furthermore, women with GDM, during pregnancy, adopted a healthier lifestyle (more likely to have low-fat foods and high fibre carbohydrates and less

likely to have added sugars and energy-dense snacks) after GDM diagnosis, when compared to women without GDM.

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CONTENTS

Contents

LIST OF TABLES

ABBREVIATIONS

ACOG	American College of Obstetrics and Gynecology
ADA	American Diabetes Association
aHEI	alternate Healthy Eating Index
aMED	alternate Mediterranean
AUR	Area under the Receiver
BMI	Body Mass Index
CCHIP	Community Childhood Hunger Identification Project
CHC	Community Health Centre
CI	Confidence Interval
Cm	Centimetres
CVD	Cardiovascular diseases
DASH	Dietary Approached to Stop Hypertension
DM	Diabetes Mellitus
FAO	Food and Agriculture Organization
FASD	Fetal Alcohol Spectrum Disorders
FFQ	Food Frequency Questionnaire
G	Grams
GDM	Gestational Diabetes Mellitus
GI	Glycaemic Index
GSH	Groote Schuur Hospital
HbA1c	Glycated haemoglobin
HDL	High-density Lipoproteins
IADPSG	International Association of Diabetes and Pregnancy Study Groups
IQR	Interquartile Range
Kg/m2	Kilogram per meters squared
LDL	Low-density Lipoproteins
LGA	Large for Gestational Age
MedDiet	Mediterranean Diet
MET	Metabolic Equivalent
Mmol/l	Millimoles per litre
MUAC	Mid-upper Arm Circumference
MNT	Medical Nutrition Therapy

NICE	National Institute for Health and Care Excellence
n	Number
NCDs	Noncommunicable diseases
OGTT	Oral Glucose Tolerance Tests
OR	Odd Ratio
P	Probability
PA	Physical Activity
Ref no	Reference number
RR	Respiratory Rate
SA	South Africa
SDs	Standard Deviation
SEMDSA	Society of Endocrinology, Metabolism and Diabetes of South Africa
SSB	Sugar-sweetened Beverages
T1DM	Type 1 Diabetes Mellitus
T2DM	Type 2 Diabetes Mellitus
TFEQ-R18	Three Factor Eating Questionnaire-Revised 18 Items
UCT	University of Cape Town
UK	United Kingdom
US	United States
USPSTF	US Preventive Services Task Force
Vs	Versus
WHO	World Health Organization

Chapter 1: Introduction

1.1 Introduction

The American Diabetes Association (ADA) defines gestational diabetes mellitus (GDM) as diabetes mellitus diagnosed in the second or third trimester of pregnancy which does not meet the criteria of overt diabetes mellitus (DM) (ADA, 2020b). The pathophysiology involved in GDM development is not well known, but it has been associated with the hormonal changes that occur during pregnancy. Hormones from the placenta, which help in the development of the baby, may undermine insulin action in the mother's body, thus leading to insulin resistance (ADA, 2020b). GDM occurs when the pancreatic *B* cells do not produce sufficient insulin to meet the increased requirements of insulin in late pregnancy (Rajput et al., 2013, Buchanan et al., 2012). Without enough insulin, glucose cannot be sufficiently absorbed from the blood into the muscle and adipose tissues for conversion into glycogen hence leading to hyperglycaemia (Adam and Rheeder, 2017a). Pregnant women may need up to three times as much insulin to overcome insulin resistance.

There is an increase in GDM prevalence, recently it is reported to be at 14% globally and 14.2% in Africa (Wang et al., 2022). According to International Diabetes Federation, 1 in 8 live births are affected by GDM (IDF, 2019). A systematic review of the global prevalence of GDM reported the highest regional prevalence in the Middle East and North Africa at 27.6% and the lowest in North America and Caribbean at 7.1% (Wang et al., 2022). In South Africa, a range of 1.6% to 8.8% prevalence was reported in a systematic review (Macaulay et al., 2014). Moreover, a cohort study conducted in Johannesburg that compared GDM prevalence using different diagnostic criteria found a 15.2% GDM prevalence when the International Association Of Diabetes and Pregnancy Study Groups (IADPSG) criteria was used (Adam and Rheeder, 2017a). Macaulay et al. (2014), further stated that there is little knowledge of GDM prevalence in Africa hence the need for more research on the prevalence of GDM in Africa.

GDM is a condition of great concern to public health since it affects the health of both the mother and her offspring. Pregnant women with GDM are at risk of developing other pregnancy-related complications such as hypertension, preeclampsia, obesity, and caesarean section births (Muche et al., 2020, McIntyre et al., 2019). Moreover, research shows that women who have gestational diabetes are likely to develop T2DM after pregnancy (Li et al., 2021). The negative effects of GDM on the infant include macrosomia, shoulder distortion during birth due to macrosomia, increased risk of stillbirth, and risk of developing diabetes later in life (Wahabi et al., 2014, Muche et al., 2020). Moreover, research on animals and humans have indicated that the offspring of women with GDM are at risk of developing GDM, diabetes, and obesity in adulthood (Gao et al., 2022, Dalrymple et al., 2022). These studies are in line with a study conducted in Denmark which found a positive relationship between children born to GDM mothers and the risk of developing diabetes mellitus in their adulthood (Erem et al., 2015b).

Several risk factors for the development of gestational diabetes have been identified and are grouped into underlying, modifiable, non-modifiable and intermediate risk factors. Underlying socioeconomic, cultural, political and environmental risk factors for GDM include globalisation and increased urbanisation. Rajput et al. (2013), conducted a study in India where they found that mothers with a higher socioeconomic status had a greater risk of developing GDM. The authors further reported that these observations could be based on the probability that women with high economic status could be older, with a higher body mass index (BMI), or living sedentary lifestyles. On the contrary, current statistics show higher prevalence rates of diabetes and other lifestyle diseases in low and middle-income countries (IDF, 2019).

Modifiable risk factors are factors that can be changed and include diet, physical activity, alcohol and tobacco use. Research shows that moderate physical activity during pregnancy helps in weight management, therefore reducing the risk of gestational diabetes (Laredo-Aguilera et al., 2020). Moreover, adherence to healthy dietary patterns such as alternate Mediterranean (aMED), Dietary Approached to Stop Hypertension (DASH) and alternate Healthy Eating Index (aHEI) have been associated with a lower risk of GDM (Tobias et al., 2012). Additionally, dietary interventions, such as a low glycaemic index diet and plant-based diet have been shown to reduce insulin resistance observed in pregnancy, therefore reducing the risk of GDM and its effects (Wang et al., 2021b, Zhang et al., 2018). However, some dietary factors before pregnancy have been identified as potential risk factors for the development of GDM (Zhang et al., 2021a) and include increased intake of sugar-sweetened cola ($\geq$5 servings/week) (Chen et al., 2009, Gamba et al., 2019), heme iron intake (Bowers et al., 2011, Chen et al., 2022), fried foods (Bao et al., 2014, Zadeh et al., 2020) and animal fat (Bowers et al., 2012).

Non-modifiable risk factors are factors that cannot be changed and include maternal age, ethnicity and family history of GDM. GDM prevalence increases with maternal age and the optimum pregnancy period for reducing the risk of GDM is below the age of 30 years (Erem et al., 2015b, Su et al., 2021). Ethnic disparities such as genetics and other factors may influence GDM prevalence and outcomes (Yuen et al., 2018). Women who have had diabetes in their previous pregnancies are more likely to have it in their subsequent pregnancies (Morikawa et al., 2021). A systematic review with 19,053 participants reported that African American women, Hispanic women and Asian women had a high GDM recurrence rate as compared to women from other races such as non-Hispanic women (Schwartz et al., 2015).

Intermediate risk factors for GDM such as access to screening, raised blood glucose, overweight and obesity are the consequences of modifiable and non-modifiable risk factors such as genetics, family history and maternal age and include raised blood glucose and overweight/obesity. Obesity in pregnancy increases the possibilities of caesarean sections, pre-eclampsia, macrosomia and gestational diabetes (Alwash et al., 2021). Therefore, average healthy body weight is recommended for women throughout their reproductive life to lower their risk of gestational diabetes (Zhang et al., 2014)(Yong et al., 2020b).

According to the US Preventive Services Task Force (USPSTF), women at 24 weeks of gestation or after should be screened for GDM, to improve maternal and foetal outcomes (Force, 2021). The screening process can be universal, where all pregnant women are checked for GDM, or selective, in which women with a high risk for GDM are screened (Ragea et al., 2022). Selective screening uses known risk factors such as older maternal age, family history, overweight/obesity and cigarette smoking (Tieu et al., 2014, Nwali et al., 2021). In many countries and especially low and middle-income ones, selective screening is done because of the high medical costs that would be incurred if universal screening was to be done. A recommendation on affordable, accessible and applicable GDM screening and diagnostic management strategies is needed in South Africa (Dias et al., 2019b).

There are several diagnostic criteria for GDM. The International Association of Diabetes and Pregnancy Study Groups (IADPSG) criteria involves a 75g oral glucose tolerance test at 24-28 weeks gestation done on all pregnant women not known to have prior diabetes (Bhavadharini et al., 2016). In South Africa, at-risk pregnant women undergo a two-hour 75g glucose tolerance test (OGTT) at booking and at 24-28 weeks gestation to screen for GDM according to SEMDSA (Society of Endocrinology, Metabolism and Diabetes of South Africa) (Webb, 2018). SEMDSA has adopted the WHO 2013 GDM screening guidelines which are: fasting blood glucose of 5.1-6.9 mmol/l, and/or ≥10 mmol/l at 1 hour, and/or 8.5-11 mmol/l at 2-hours post a 75g oral glucose load.

There is enough evidence regarding risk factors for GDM development from high-income countries (Zhu and Zhang, 2016, Hedderson et al., 2010, Dobjanschi and Miulescu, 2015). Two systematic reviews on the prevalence and risk factors for GDM in Africa highlighted the fact that limited research has been conducted within Africa and only a few studies focus on GDM risk factors (Mwanri et al., 2015b, Macaulay et al., 2014). Furthermore, only four South African studies were included in the systematic review, mainly addressing GDM prevalence and were conducted before the year 2010 (Mwanri et al., 2015b).

Diet and exercise play a big role in the treatment of GDM (Ali et al., 2021). Moreover, SEMDSA recommends nutrition education on lifestyle changes to help control/prevent GDM during antenatal clinics (Webb, 2018). Diet intervention includes increased intake of; fruits and vegetables, wholegrain starch, all types of fish, low saturated fat foods, legumes, low-fat sugar-free dairy products and vegetable fat. On the other hand, the intake of commercially hydrogenated fats, processed and fatty red meat, sugar and alcohol should be reduced (Webb, 2018).

This thesis aimed at investigating risk factors for GDM (non-modifiable, underlying and intermediate) in Cape Town, South Africa. Furthermore, we investigated the differences between women with GDM and those without GDM as a result of interventions for modifiable risk factors.

There is no study known to us that has investigated the difference in intervention outcomes between pregnant women with GDM and those without in Africa. Therefore, this study is important for our population.

1.2 Research Aim

1. To investigate the underlying, non-modifiable and intermediate risk factors for the development of gestational diabetes mellitus in women living in Cape Town, South Africa.
2. To compare lifestyle factors between participants with GDM and those without GDM, living in Cape Town, South Africa.

1.3 Research Objectives

The **primary objectives** of the research were:

- To determine the risk factors for the development of GDM among women attending Groote Schuur hospital and Vanguard community health clinic in Cape Town using a case-control study design.

- To compare lifestyle changes such as diet, physical activity, alcohol and smoking between women with GDM and those without GDM, attending Groote Schuur hospital and Vanguard community health clinic in Cape Town.

The **secondary objectives** were to compare the following factors for the development of GDM between cases and controls:

- Underlying risk factors (income, housing, grants, education, household food security)

- Modifiable risk factors (dietary intake, alcohol intake, tobacco use and substance abuse, eating behaviours/patterns, physical activity patterns)

- Non-modifiable risk factors (family history of GDM, maternal age and ethnicity)

- Intermediate risk factors (Previous GDM, previous macrosomia, number of previous pregnancies, blood pressure, glycosuria, weight status and weight history)

1.4 Contribution by student

The candidate was responsible for;

- Conceptualizing the research study
- Recruitment of patients
- Data collection. Administration of questionnaires for both cases and controls at Groote Schuur and Vanguard hospital, which included anthropometric measurements.
- Conducting one on one interviews with patients and organizing for incentives.
- Data entry and clean up in excel sheet
- Data analysis with the assistance of data analyst and compiling tables
- Compiling all chapters of the thesis

1.5 Outline of Thesis

Chapter 1 is a general introduction to GDM risk factors and a comparison of lifestyle changes between women with GDM and women without GDM. Chapter 2 focuses on the literature review of GDM risk factors. This includes the underlying, non-modifiable, modifiable and intermediate risk factors of GDM. Additionally, an existing literature review comparing lifestyle changes between women with GDM and women without GDM has also been highlighted in his chapter. The next two chapters are in the form of empirical articles that could be submitted for publication. Both chapters consist thus of an abstract, introduction, methods, results, discussion and conclusion. The methods section of the articles may contain repeated information. Chapter 3 is the first article entitled "Underlying, non-modifiable and intermediate risk factors for the development of Gestational Diabetes Mellitus, in Cape Town", which covers our primary objective. Our secondary objective is addressed in chapter 4, the article is entitled "Comparison of lifestyle changes between Women with Gestational Diabetes Mellitus and those without". The final chapter (Chapter 5) is the discussion of the results in chapter 3 and chapter 4, and the final conclusions and recommendations.

Chapter 2: Literature Review

2.1 Introduction to GDM Risk Factors

Gestational Diabetes Mellitus (GDM), is the most common complication in pregnancy and is estimated to affect about 14.28% of pregnancies in Sub-Saharan Africa (Muche et al., 2019a). GDM prevalence varies depending on the screening criteria used, and the new International Association of Diabetes in Pregnancy Study Groups (IADPSG) criteria further increase the incidence of GDM by 2-3 fold (Adam and Rheeder, 2017a, Saeedi et al., 2021). This was observed in a study conducted in South Africa, which reported 25.8% GDM prevalence when using the IADPSG criteria (Adam and Rheeder, 2017a).

Advanced maternal age, increased sedentary lifestyle, growing rates of obesity, ethnicity, family history of diabetes and previous GDM (McIntyre et al., 2019, Rajput et al., 2013, Wang et al., 2021b) have been reported to influence GDM risk. These risk factors can be classified as underlying, modifiable, non-modifiable, and intermediate risk factors. Understanding risk factors for GDM is important, and can help in managing the increasing prevalence.

GDM has both short and long-term negative effects on both the mother and the offspring (ADA, 2020b, Vounzoulaki et al., 2020). As Vounzoulaki et al. (2020) and Chivese et al. (2019a) note, in women, it is associated with an increased risk of Type 2 Diabetes Mellitus (T2DM) and preeclampsia, while for the offspring it increases the risk of macrosomia, neonatal hypoglycemia, hyperbilirubinemia, neonatal respiratory distress, and childhood obesity (ADA, Chivese et al., 2019a, Depla et al., 2021). This, therefore, buttresses the need to understand the modifiable risk factors for GDM treatment and management which may significantly reduce the negative perinatal and maternal outcomes.

Dietary modification, other lifestyle changes, and medication are used to treat GDM and better pregnancy outcomes for women with GDM (Zhuang et al., 2020, McIntyre et al., 2019). Findings from literature investigating the benefits of both diet and physical activity and weight management have reported a 45% reduction in GDM incidence if women follow a healthy lifestyle before and during pregnancy, as these programs result in maintenance of normal glucose levels (Bao et al., Webb, 2018).

2.2 Underlying Risk Factors for GDM

2.2.1 Globalisation, Urbanisation and nutrition transition

Globalisation has been linked with the rapid increase in the prevalence of non-communicable diseases (NCDs) such as diabetes (Zimmet et al., 2014, Beaglehole and Yach, 2003). The current and future patterns of non-communicable diseases are affected by globalisation, therefore, policymakers should take these outcomes into consideration (Vineis et al., 2014). Moreover, increasing urbanisation brings about several challenges such as air pollution, improper waste disposal, poor housing, lack of water, and lifestyle changes related to modernisation (Qing, 2018). Additionally, low-and middle-income countries are experiencing a nutrition transition towards diets that are high in processed meat and high-fat foods, sugars, and refined carbohydrates, from healthier diets (Steyn et al., 2012, Popkin, 2015, Maheshwari et al., 2019). These diets are reported to increase the risk of GDM (Bao et al., 2014).

2.2.2 Socioeconomic status

Socioeconomic status is defined as a measure of one's combined economic and social status, measured by education, occupation and income amongst other variables, and tends to be positively associated with better health (Stringhini et al., 2018, Kivimäki et al., 2020). Pregnancy complications such as infant mortality, and lower birth weight among other complications may result due to lower socio-economic status (Olonade et al., 2019, Malik et al., 2022). Furthermore, low socioeconomic status was reported to be associated with an increased risk for obesity and diabetes in both cross-sectional and prospective studies (Volaco et al., 2018), and a high maternal income was reported to decrease GDM incidence (Rönö et al., 2019). According to Song et al. (2017), in a study conducted in China, lower educational level was linked with an increase in GDM risk, while no significant association was observed in household income. On the contrary, lower education levels were linked with decreased GDM prevalence in a study by (Rajput et al., 2013), with the highest prevalence being among women who were graduates or above. Nonetheless, in Pakistan no association was reported between high socioeconomic status and risk for GDM (Khan et al., 2013b). Khan et al. (2013a), attributed their finding to the possibility that social status may have been differently defined across the different studies.

2.2.3 Food insecurity

Food insecurity is defined by FAO (Food and Agriculture Organisation) as a situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active, healthy life (FAO, 2022). Food insecurity is often associated with poverty, low household income, and a decrease in maternal dietary diversity (Na et al., 2016).

Food insecurity during pregnancy has been associated with increased weight gain and pregnancy complications such as low birth weight and gestational diabetes (Laraia et al., 2010, Yadegari et al., 2017, Ivers and Cullen, 2011). According to Laraia et al. (2010), women living in marginally food-secure households in the US (United States) had a 2-fold higher risk for GDM after adjustment for age, race, educational level, and physical activity, when compared to women who were food secure. Moreover, household food insecurity and marginal food security combined were both associated with greater odds of developing GDM [OR 2.38, (95% CI: 0.99, 5.73)]. Food insecurity may mean access to poor-quality food (Mbow et al., 2019) such as high glycemic index foods, linked to increased weight gain and GDM (Zhang et al., 2021a).

2.3 Modifiable Risk Factors

Modifiable risk factors can be changed when measures are taken (ADA, 2016).

2.3.1 Dietary patterns

A meta-analysis and systematic review of longitudinal and cohort studies reported that diets such as the Dietary Approaches to Stop Hypertension (DASH) diet (Asemi et al.), the Mediterranian Diet (MedDiet), the Alternate Healthy Eating Index (AHEI) diet (Tobias et al.), and the alternate Mediterranean Diet (aMED) (Tobias et al.) were associated with a reduced risk (15-38%) of GDM (Chen et al., Tobias et al., 2012). Common components between DASH and aMED diets include a higher intake of fruits and vegetables and a decrease in intake of processed and red meat (Tobias et al., 2012). Micronutrients found in fruits and vegetables help to prevent metabolic deterioration and were reported to reduce the risk of T2DM (Hamer and Chida, 2007). In addition, a prudent diet rich in fruits, leafy vegetables, poultry, and fish was reported to reduce the risk GDM, even after adjustments for GDM risk factors (Zhang and Ning, 2011, Zhang et al., 2014).On the other hand, Western diets, high in red meat, processed meat and refined carbohydrates were reported to increase the risk of GDM in the Nurses' health study II (Bowers et al., 2011).

Additionally, three dietary patterns; 1.) "high refined grains, fats, oils, and fruit juice", 2.) "high nuts, seeds, fat and soybean; low milk and cheese" and 3.) "high added sugar and organ meats; low fruits, vegetables, and seafood" were reported to increase the risk of GDM in a study conducted in the US (Shin et al., 2015). Among the three patterns, the strongest relationship to GDM risk was found with the "high added sugar and organ meat; low fruits, vegetables, and seafood".

2.3.1.1 Macronutrients

Some studies have investigated the role of macronutrients in GDM development (Bao et al., 2014, Bao et al., 2013, Looman et al., 2018). For example, a Nurses' Health Study II, with a large sample size of 21411 singleton pregnancies, found that the intake of diets rich in animal protein was significantly associated with GDM risk while diets rich in vegetables were not associated with GDM development (Bao et al., 2014). Bao et al.'s (2014), study also reported an increased risk of GDM with higher consumption of potatoes before pregnancy and a 9-12% decreased risk of GDM when vegetables, legumes, and whole grains were replaced with two servings of potatoes (Bao et al., 2016).

It has been reported that high intake of red meat and processed meat increased risk of GDM development (Zhang and Ning, 2011, Schoenaker et al., 2016). According to Zhang et al. (2011), each serving of red meat per day increased the risk of GDM by 66% while processed red meat increased GDM risk by 47%.

Meanwhile, Bowers et al. (2012), reported that the consumption of animal fat increased GDM risk while replacing animal fat with vegetable fat reduced the risk of GDM [RR: 0.93; (95% CI: 0.88, 0.98; P=0.01)] (Bowers et al., 2012). Individuals with the highest quantile for animal fat intake had the highest (90%) risk of GDM compared to pregnant women with the lowest quantile of intake. However, there was no link between total omega 3 or total omega 6 fatty acids intake and the risk of GDM. Egg intake (≥7eggs/week) (Qiu et al., 2011) and higher intake of cholesterol before and during pregnancy beyond the daily recommended intake of 300mg/day have also been associated with increased GDM risk (Qiu et al., 2011, Schoenaker et al., 2016).

2.3.1.2 Micronutrients

Micronutrients have been reported to influence GDM development (Zhang et al., 2015, Vaidya and Williams, 2012). Consumption of a diet rich in micronutrients including vitamin A, vitamin C, vitamin B6, vitamin B2, dietary fibre, potassium, calcium, and folate was associated with reduced risk of GDM (Machairiotis et al., 2021, Li et al., 2022). In a meta-analysis, vitamin D deficiency was reported to increase the risk for GDM development (Zhang et al., 2015). Vitamin D is important for glucose regulation and promotes insulin sensitivity(Vaidya and Williams, 2012). Bowers et al. (2011), reported a positive association between pre-pregnancy heme iron intake and GDM but did not find a significant association between total non-heme and supplemental iron intakes with GDM risk (Bowers et al., 2011). Iron is a strong pro-oxidant, therefore, a high intake of iron may impair glucose metabolism.

2.3.1.3 Dietary fibre and glycaemic index

A study conducted among Chinese women reported a decreased risk of GDM development for women who consumed higher dietary fiber before pregnancy, in their first and second trimesters (Zhang et al., 2021a). A high glycaemic index diet has also been associated with increased GDM risk (Bao et al., 2016, Zhang et al., 2014, Zhang et al., 2021b). Additionally, a high-content complex dietary fiber powder used in nutrition therapy for pregnant women with GDM in Shanghai hospitals was reported to have a significant effect on glycemic control, lipid control, weight control and pregnancy outcomes in patients with GDM (Wang et al., 2021a).

2.3.1.4 Sugar-sweetened beverages

High consumption of sugar-sweetened beverages including regular soda, fruit drinks (sweetened bottled waters and fruit juices and nectars with added sugars), sports and energy drinks, sweetened coffees and teas, and other sugar-sweetened beverages have been associated with an increased risk of GDM and T2DM (Donazar-Ezcurra et al., 2018, Rosinger et al., 2017, Imamura et al., 2015).

In Norway, a higher intake of sugar-sweetened carbonated drinks was reported to increase macrosomia among women with GDM (Grundt et al., 2017). Although the Nurses' Health Study II found a positive association between the intake of sugar-sweetened cola and the risk of GDM development, no significant association was found for other sugar-sweetened beverages and diet beverages (Bao et al., 2014).

2.3.2 Physical Activity

Physical activity before and during pregnancy helps to control blood sugar levels during pregnancy (Laredo-Aguilera et al., 2020, Peters and Brazeau, 2019). The American College of Obstetricians and Gynecologists committee and Obstetric Practice recommends that pregnant women with or at risk of GDM should engage in 20-30 minutes of moderate-intensity exercise on most or all days of the week (ACOG, 2015). Furthermore, Aune et al. (2015), observed that 5-7 hours of physical activity weekly, lowered the risk of hyperglycemia with lower-intensity exercise being better than higher-intensity activities (Aune et al., 2015).

A 55% reduced risk of GDM onset was reported among women who were more physically active compared to those who were less physically active (OR 0.45[95% CI: 0.28-0.75] ;p 0.002) (Bowers et al., 2011). Additionally, a study with 14,437 participants reported that living a healthy lifestyle before pregnancy lowered the risk of GDM by 41% , when compared with women who did not live healthy before pregnancy (Zhang et al., 2014).

Other studies in different populations have also reported a reduction in GDM risks and blood sugar levels among women who engaged in moderate to high physical activity (Leng et al., 2016, Ehrlich et al., 2017). For instance, Deierlein et al. (2012), observed that hyperglycemia risks were lowered by 27% among women who engaged in any physical activity in a week. Moreover, in South Africa, SEMDSA recommends physical activity to help control blood sugar levels and maintain healthy body weight (Webb, 2018). Therefore, pregnant women need to be physically active during pregnancy to reduce their risk of developing GDM.

2.3.3 Alcohol Use

Alcohol intake in pregnancy directly affects the foetus because it passes through the placenta to the foetus and exposes it to foetal alcohol spectrum disorders (FASD) (Khalil and O'Brien, 2010). Alcohol consumption was reported to affect glucose regulation, when consumed in high doses low and medium intake lowered the risk of abnormal glucose regulation (Cullmann et al., 2012).

On the contrary, Knott et al. (2015), in a systematic review reported a decrease in T2DM risk when alcohol was taken in moderation, i.e. lower than 63g per day. However, the risk was found to increase with consumption above this threshold (Knott et al., 2015). Knott et al. (2015), attributed their findings to overestimation by studies that used control groups consisting of less healthy former drinkers.

2.3.4 Tobacco Use

Cigarette smoking and GDM onset has not been well exploited, and the available evidence is contradicting (Zhang et al., 2014, Simas et al., 2014, Erem et al., 2015a). For Instance, Zhang et al. (2012), reported that not smoking before pregnancy was associated with a lower risk for GDM development (Zhang et al., 2014), while Erem et al. (2015a), found an inverse association between current smoking in pregnancy with GDM risk (Erem et al., 2015a). Moreover, studies conducted in the United States (Bao et al., 2016) and Sweden (Mattsson et al., 2013) reported that smoking in pregnancy increased the risk of GDM development in daughters. On the contrary, no relationship between smoking of cigarrete prior to pregnancy and GDM was reported among Hispanic women (Simas et al., 2014).

2.4 Non-modifiable Risk Factors

Non-modifiable risk factors cannot be controlled or changed.

2.4.1 Advanced Maternal age

Advanced maternal age is a well-established risk factor for GDM development. This has been reported by a study that investigated 76158 pregnant women in the United Kingdom (UK), which found that advanced maternal age increased GDM risk [OR, 1.88 (95% CI: 1.55-2.29; $p<0.001$)] (Khalil et al., 2013). A systematic and meta-analysis study with over 120 million participants reported a linear increase in GDM risk with successive age groups. Above the age of 18 years, every one-year increase in maternal age increased GDM risk by 7.90% for the overall population, 12.74% among Asians, and 6.52% among Europid (Li et al., 2020b).

2.4.2 Medical and family history

Previous GDM, a family history of diabetes, a history of stillbirth, previous macrosomia, and a history of previous preterm births increase the risk of GDM development (Lee et al., 2018c, McIntyre et al., 2019, Rajput et al., 2013).

2.4.2.1 Previous GDM

Pregnant women with a history of GDM have an increased risk of developing GDM in their future pregnancies (Wei et al., 2022, Egan et al., 2021). Wang et al. (2019), in a study conducted in China, stated a 55% recurrence rate of GDM in the subsequent pregnancy (Wang et al., 2019), while Kruse et al. (2015) reported a 47.2% GDM recurrence rate in a Denmark study (Kruse et al., 2015). Moreover, Erem et al. (2015), in a study conducted in Turkey support

Wang et al. (2019) and Kruse et al. (2015) studies that GDM is likely to recur in subsequent pregnancies (Erem et al., 2015a). Notably, lifestyle interventions through exercise and healthy eating may break the chain and reduce the risk of GDM (Kruse et al., 2015).

2.4.2.2 Family history of Type 2 Diabetes Mellitus

A family history of diabetes is an important risk factor for GDM development (Moosazadeh et al., 2017a, Mwanri et al., 2015b, Lewandowska, 2021, Preda et al., 2022). Moosazadeh et al. (2017a) found a 3.46-fold increase in GDM risk with a family history of diabetes while Lewandowska reported a 3.68-fold increase in GDM-1 risk for women with diabetes in a father, 2.13-fold increase for women with diabetes in a mother and 2.34-fold increase for women with diabetes history in a grandmother (Moosazadeh et al., 2017a, Lewandowska, 2021). Therefore, early lifestyle interventions are needed for women from families with a history of diabetes.

2.4.3 Other comorbidities

2.4.3.1 Hypertension

Hypertension and T2DM are both metabolic syndromes and often occur together (Lewandowska et al., 2020, Kibret et al., 2019). Prehypertension before and during early pregnancy has been reported to increase the risk of developing GDM during pregnancy (Black et al., 2015, Hedderson and Ferrara, 2008). In other instances, hypertension occurs as a result of GDM (McIntyre et al., 2019).

2.4.3.2 Preeclampsia

Preeclampsia is a pregnancy complication characterized by high blood pressure and proteinuria (Tranquilli et al., 2013). Preeclampsia and GDM often exist together in pregnancy and have common risk factors which include advanced maternal age, multiple gestations, and increased BMI before pregnancy (Schneider et al., 2012). A history of preeclampsia in previous pregnancies increases the risk of GDM development in a subsequent pregnancy (Lee et al., 2017a, Yang and Wu, 2022). According to Lee et al. (2017), women with preeclampsia only in the first pregnancy had 1.2 times increased risk of GDM in subsequent pregnancy while a combination of preeclampsia and GDM in first pregnancy further increased the risk of GDM in subsequent pregnancy by 5.9-fold when compared to women without previous preeclampsia and GDM. Moreover, preeclampsia and GDM in pregnancy increase the risk of developing diabetes after pregnancy (Feig et al., 2013, Engeland et al., 2011).

2.4.4 Ethnicity

Ethnicity is defined as identification with a particular type of ethnic character, quality, or peculiarity (Isajiw, 1974). Some ethnic groups are considered to be at higher risk of GDM as compared to ther ethnic groups, however, the reason for the differences is not clear. A higher GDM prevalence of 11.1% was reported among Asian Indians and a lower prevalence of 4.1% was reported among non-Hispanic women, in a study conducted in the US (Hedderson et al., 2010). Further, Hedderson et al. (2010) reported differences in GDM prevalence among women from different ethnic groups, in a study conducted in the US. Moreover, Tsai et al., in a study conducted in Hawaii support Hedderson et al. (2010) findings where more Filipina women (13.1%) and Hawaiian/ Pacific Islanders (12.1%) had GDM when compared to white women (7.4%) (Tsai et al., 2013).

Additionally, in rural Taiwan, the aboriginal Taiwanese women had a higher GDM prevalence when compared to non-aboriginal women (Lin et al., 2015). Having identified GDM at-risk women based on ethnic disparities, there is a need for early screening and education to reduce GDM development. Moreover, Yuen and Wong. (2015), in a study conducted in Australia emphasized that education and management of GDM in hospitals should be considerate of the different ethnic groups (Yuen and Wong, 2015).

2.4.5 Intermediate Risk Factors

Intermediate risk factors are the consequences of modifiable and non-modifiable risk factors and include raised blood glucose, raised blood pressure, overweight, and obesity (ADA, 2018).

2.4.5.1 Weight status before pregnancy

Being overweight and obese prior to pregnancy predisposes women GDM in pregnancy. A higher BMI prior to pregnancy was reported to increase GDM onset in pregnancy, in the Nurses' Health Study II conducted in the United States. Interestingly, Zhang et al. (2015) reported an increased GDM risk with high-end of the normal BMI range (23.0-24.9) (Zhang et al., 2014). In systematic reviews focusing on African countries, Mwanri et al. (2015a) and Muche et al. (2019a) reported an increased risk of GDM with overweight and obesity (Muche et al., 2019a, Mwanri et al., 2015a). Moreover, Hantoushzadeh et al. (2016), found a 2.8-fold GDM risk for obese women and 1.5-fold risk for overweight women prior to pregnancy (Hantoushzadeh et al., 2016).

On the contrary, no association was reported between pre-pregnancy obesity without metabolic complications and GDM risk in a study conducted in Thailand (Kongubol and Phupong, 2011). The above study had a smaller sample size, which might explain the observations.

2.4.5.2 Weight status during pregnancy

Women are expected to gain weight during pregnancy because of the growing foetus and other factors surrounding pregnancy. However, a lot of weight gain in pregnancy has been reported to increase complications such as GDM (Muche et al., 2019a, Mwanri et al., 2015a). Several studies conducted in Africa (Muche et al., 2019a, Mwanri et al., 2015a, Dias et al., 2019a), Asia (Lee et al., 2018c, Rajput et al., 2013) and western countries (Zhang et al., 2014) have reported an increased GDM risk with overweight and obesity during pregnancy.

However, limiting energy intake from total fats and sugars, and increasing fruits, vegetables, legumes, whole grains, and nuts, as well as regular exercise (150 minutes spread through the week), is important for women in the reproductive age to reduce overweight and obesity and decrease GDM risk (WHO, 2017).

2.4.5.3 Weight history

There is a relationship between birth weight and metabolic disorders such as obesity and insulin resistance (Vejrazkova et al., 2015). Vejrazkova et al. (2015), reported increased insulin secretion and decreased peripheral insulin sensitivity with low birth weights of women with GDM in a retrospective study. Moreover, a study conducted among Caucasian polish women reported an 11% increased risk of GDM with each 500g decrease in birth weight (Ogonowski et al., 2014). Furthermore, Zhu et al (2017) study conducted in China supports Ogonowski et al., (2014) study, as they found an increased GDM risk with low birth weight among Chinese women (Zhu et al., 2017). According to Zhu et al. (2017) study, birth weight above 3000g may be important in reducing GDM risk among female offspring. On the other hand, obesity and being overweight before pregnancy (childhood, adolescent years, and young adulthood) is also a risk factor for GDM development (Shin et al., 2015).

2.5 GDM Screening

GDM screening is often done at 24-28 weeks of gestation, since insulin resistance spikes during trimester 2. However, some women cannot cope with the increased insulin needs, therefore, they end up with increased glucose levels (Rani and Begum, 2016). GDM screening may be implemented universally, where all pregnant women are screened or selectively where only women high-risk women are screened. Risk factors used in selective screening include; increased maternal age, previous history of GDM, increased BMI among other risks factors. Universally, no single diagnostic method is used for GDM, but IADPSG (International Association of Diabetes and Pregnancy Study Group) where a 2-hour 75g Oral Glucose Tolerance Test (OGTT) is performed is commonly used (Hartling et al., 2012). Society of Endocrinology, Metabolism, and Diabetes of South Africa (SEMDSA) recommends the use of either fasting blood glucose ≥7mmo/L or a two-hour post-load plasma glucose OGTT ≥11mmol/L (millimoles per litre) to confirm T2DM in symptomatic patients (SEMDSA, 2017).

2.6 Intervention and Treatment

2.6.1 Diet

Vast evidence has been reported on the role of low glycaemic index foods (Moses et al., 2009), modification in the quality and quality of carbohydrates, protein (Sarathi et al., 2016), fat intake (Hernandez et al., 2016), and energy restriction for GDM treatment and management (Zhang et al., 2014, Zhang and Ning, 2011, Viana et al., 2014). Additionally, beneficial factors have been reported in aMED diet, consisting of high fruit and vegetable consumption while reducing red and processed meats consumption (Tobias et al., 2011). The micronutrients found in fruits and vegetables help to prevent metabolic deterioration and therefore, improve systemic oxidative stress (Hamer and Chida, 2007).

The type of maternal diet and carbohydrate content influence their glucose concentration; with different carbohydrate-rich foods producing different GI (Glyceamic Index) (Walsh et al., 2012). Consumption of a low GI diet by women with GDM has been associated with better pregnancy outcomes (Wan et al., 2019). A meta-analysis reported that diets with low GI reduced the need for insulin therapy and macrosomic babies. Additionally, Moses et al. (2009), reported that consumption of a low GI diet among women with GDM effectively reduced the need for insulin treatment compared to women with GDM who took a high GI diet (Moses et al., 2009). According to a study conducted by Viana et al., a low GI diet was reported to lower glucose intolerance and lower macrosomia, while restricted diet and low carbohydrate diets did not affect pregnancy outcomes (Viana et al., 2014). Carolan on the other hand also noted the importance of a low glycaemic index diet and exercise in reducing maternal glucose levels, normal infant birth weight, and maternal weight gain during pregnancy (Carolan-Olah, 2016). On the contrary, Tieu et al. (2017), found no differences between dietary glyceamic index advice in GDM risk reduction (Tieu et al., 2017). The possible explanation of the difference observed in this study is small sample size.

Although DASH dietary patterns have previously been reported to control hypertension, their benefits have also been reported in GDM management (Asemi et al., 2014). Its high fibre content and micronutrient levels have been attributed to a low GI index (Azadbakht et al., 2011). An Iranian study investigating the effects of DASH on pregnancy outcomes in GDM reported that consumption of the DASH diet by women with GDM for 4 weeks reduced the need for insulin treatment compared to the control diet comprising a higher number of grains, simple sugars, and fats and lower number of vegetables, fruits, dairy, nuts, seeds, legumes, and fish (Asemi et al., 2014).

Protein-rich diets have also been reported to be preventive against GDM risk. In a study that evaluated the effect of a soya-based protein diet on glycemic parameters, the author reported that a soya-based protein-rich diet significantly improved glycemic parameters in the first week of nutrition therapy compared to the control diet needed (Sarathi et al., 2016). The wing's study on the other hand showed an association between dairy consumption and Pregnancy outcomes among GDM women (Anjana et al., 2019).

Table 1.1 Characteristics of a high-quality dietary pattern (Webb, 2018)

Food	**Nutrient and health benefits/consequences**
High intake of fruit and vegetables: Minimum of 5 portions per day	Increase intake of fibre that enhance satiety, Phyto-nutrients, vitamins and minerals that combat oxidative stress.
Starchy foods should be wholegrain: Corn, barley, pearl-wheat, rolled oats, unrefined maize, wild/brown rice and wholegrain breads	Contain B vitamins, vitamin E and fibre that improve glycaemic control and enhance satiety.
Encourage intake of all types of fish: Especially fatty fish with a high omega 3 content such as sardines	Low saturated fat content, good source of protein, omega 3-fatty acids, selenium, magnesium and vitamin D
Encourage intake of legumes: Soya beans, a variety of dry beans, lentils and chick peas	Promote healthy lipid profile, good source of fibre and protein

Food	**Nutrient and health benefits/consequences**
Use of low fat sugar free daily products: Low fat plain yoghurt and low fat milk	Provide calcium, vitamin D, and magnesium. Good source of protein with a low saturated fat content
Use of vegetable fats: Such as nuts and seeds, avocado pear, olives, plant oils (canola, olive, sunflower etc. Avoid tropical oils (e.g. coconut and palm cornel oil)	Replace saturated fatty acids in the diet with unsaturated fatty acids tend to reduce the risk of cardiovascular disease (CVD). Tropical oils contain low density lipoproteins (LDL) cholesterol raising fatty acids
Reduce intake of commercially hydrogenated fats: Commercially deep fried foods, fast foods and baked items contain high amounts of trans fatty acids	Trans-fatty acids raise total and LDL cholesterol, decrease hidh density lipoproteins (HDL) cholesterol and increase inflammation.
Reduce intake of processed meats and fatty red meat: Bacon, all types of sausages, polony and deli meats.	High content of salt, nitrates, haem-iron and saturated fat.
Reduce intake of sugars: Table sugar, honey, sugar sweetened beverages, fruit juices, sweets, desserts and baked goods	Poor nutrient content, contributes to poor glycaemic control, lipid profiles, obesity and inflammation.
If alcohol is consumed it should be in moderation: Wine, spirits, beer etc.	A high intake aggravates glycaemic control, hypertension and triglycerides.

2.6.2 Physical Activity

Exercise has been linked with reduced GDM risk, better glucose tolerance, and control of glucose metabolism by increasing glucose uptake by the skeletal muscle (Webb, 2018). Moreover, health practitioners in South Africa acknowledge the importance of providing physical activity advice to pregnant women as part of prenatal care (Watson et al., 2015). Therefore, pregnant women need to be physically active during pregnancy to reduce their risk of developing GDM.

Most trials looking at GDM have established the importance of physical activity in reducing the need for insulin and glycemic indicators. For example, low-intensity walking lowered fasting and postprandial glucose levels among the intervention group compared to the control.

Anjana et al. (2016), found that GDM women who were physically active showed a decrease in fasting and postprandial glucose levels, however, no difference in HbA1c (Glycated haemoglobin) levels was observed(Anjana et al., 2016). Women with GDM had lower levels of moderate and high intensity exercises in pregnancy compared to their counterparts in a Chinese study [70.8% vs 81.6%, P=0.191] (Leng et al., 2016). A randomised trial that aimed to evaluate the effect of resistance exercise on insulin requirement and glycemic control reported that women with GDM in the exercise group required a decreased insulin requirement compared to the control group (de Barros et al.). Another randomised control trial investigating women with GDM engaging in simple exercise was reported to have reduced levels of postprandial glucose, triglycerides, and HbA1c. Fewer women required insulin and had better pregnancy outcomes, although no significant difference was observed in fasting blood glucose (Bo et al., 2014). Halse et al. (2014), found that postprandial glucose levels and capillary glucose concentrations were reduced in women in the supervised exercise group compared to their counterparts, although no difference was observed in insulin response and post-intervention glucose ingestion (Halse et al., 2014).

Physical activity reduces the risk of GDM for women in their reproductive age (Russo et al., 2015, Leng et al., 2016, Tobias et al., 2011). Physical activity in pregnancy can be safe for the mother and her child and helps in lowering the risk of GDM and maintaining a healthy body weight (Poston, 2015). However, Nobles et al. (2015), in a randomised control trial did not report a reduction of GDM risk as a result of physical activity interventions in the second trimester of pregnancy (Nobles et al., 2015).

2.6.3 Treatment of GDM

Insulin therapy and/or the use of oral drugs such as metformin and glyburide are used in GDM treatment after dietary treatment cannot control glyceamic levels (ADA, 2018). Balsells et al. (2015), reported that insulin and metformin are more effective in GDM treatment when compared to the use of glibenclamide (Balsells et al., 2015). Moreover, oral treatments are more preferred when compared to insulin because of the fear that comes with insulin injections. However, insulin is preferred for GDM treatment due to the lack of information on the long-term safety of metformin and glyburide (ADA, 2015). GDM treatment decreases the incidence of pregnancy outcomes such as large for gestational age (LGA) births, macrosomia and shoulder dystocia in infants (Poolsup et al., 2014).

A summary of some studies that focused on dietary and physical activity interventions for GDM is presented in Table 2.2 below.

Table 2.2 A summary of some studies that focused on dietary and physical activity interventions for GDM

Author and Year	Study Design	Objectives	Sample Size	Interventions	Results	Limitations and Strengths
Tieu et al. (2017)	A systematic Review study of dietary advice interventions before 3rd Jan 2016	To assess the effects of dietary advice interventions for preventing GDM and associated adverse health outcomes for women and their babies.	11 trials n=2786 women with their babies Inclusion criteria: Interventions that assessed any type of dietary advice before testing for GDM. Studies where dietary interventions were compared with no dietary advise (standard care) were included Exclusion criteria: Studies that included interventions assessing combined dietary advice and exercise interventions.	6 trials compared dietary advice interventions with standard care. 4 trials compared low-glycaemic index (GI) with moderate to high GI dietary advice 1 trial compared specific (high fibre focused) with standard dietary advice.	A trend towards reduction of GDM was observed for women receiving dietary advice compared with standard care (Average risk ratio (RR) 0.60, 95% CI0.35 TO 1.04; 5 trials, 1279 women. P=0.07 Grade: very low-quality evidence. No clear differences were shown in the risk for GDM between low GI dietary intervention and moderate to high GI dietary advice RR 0.91, 95% ci 0.63 TO 1.31; 4 trials, 912 women: Grade: low-quality evidence. No clear difference between high fibre dietary advice groups	Strength Two review authors independently assessed eligibility for inclusion, extracted data and assessed risk of bias Limitation Only 11 trials were included in the review

Author and Year	Study Design	Objectives	Sample Size	Interventions	Results	Limitations and Strengths
					and standard dietary fibre groups; 1 trial	
Luoto et al. (2011)	Cluster randomized trial	To examine whether gestational diabetes mellitus (GDM) or new-borns' high birthweight can be prevented by lifestyle counselling in pregnant women at high risk of GDM	2271 women were screened by OGTT test at 8-12 weeks gestation. Euglycaemic women (n=339) with at least one risk factor for (body mass index>25kg/m2, glucose intolerance or new-borns macrosomia in any early pregnancy, family history of diabetes, age >40 years were included. Exclusion criteria: abnormal OGTT measurements (8-12 weeks), pre-pregnant Type 1 or 2 diabetes, inability to speak Finnish, age<18 years, substance abuse and psychiatric issues	Dietary intervention**:** based on Finnish dietary intervention, dietary counselling was done to help participants achieve a healthy diet containing ≤10% saturated fat, 25%-30% total fat, <10% sucrose of total energy intake and 25-35g/d fibre at 16-18 weeks gestation. Physical activity counselling was initiated from 8-12 weeks gestation and aimed at increasing leisure-time physical activity for those women who were not fulfilling the recommended physical activity	There were no significant differences between the intervention and the usual care group at baseline or 26-28 weeks gestation in glucose intolerance measurements. The proportion of women with GDM based on different criteria did not differ between the groups Total gestational weight gain, preeclampsia, or use of diabetic medication did not differ significantly between the groups	Limitations: Absence of late pregnancy measurement of maternal glucose intolerance thus lacks assessment of maternal endpoints close to delivery therefore high birth weight was used as a marker of longstanding glucose intolerance during pregnancy. Women and nurses on the usual care group were not blinded which may have resulted in changes in their health behaviour or counselling practice. Strengths: Physical activity counselling was enhanced at four

Author and Year	Study Design	Objectives	Sample Size	Interventions	Results	Limitations and Strengths
				(PA) and maintaining or adjusting leisure-time PA for active women. It included a recommendation of 750 metabolic equivalents (MET) minutes of moderate Intensity PA		visits and diet 3 visits and participants engaged in physical activity in their monthly visits to the clinic. An initial pilot study was conducted
Rogozinska et al., 2015	Systematic review literature search since inception to March 2014	To determine the effectiveness of nutritional manipulation in pregnancy with mainly diet-based interventions; mixed approach with diet and lifestyle; and nutritional supplements in preventing GDM.	20 RCTs (6,444 women) were included from 1761 citations.	Diet-based (n=6) Mixed approach (diet and lifestyle) interventions (n=13) Nutritional supplements (Myo-inositol n=1, diet with probiotics n=1)	Diet-based interventions reduced the risk of GDM by 33% Mixed approach interventions based on diet and lifestyle did not affect GDM (RR 0.95; 95% CI 0.89, 1.22). Nutritional supplements probiotics combined with diet (RR 0.40; 95% CI 0.20, 0.78) and myo-inositol (RR 0.40; 95% CI 0.16, 0.99) were assessed in	Strengths Studies included had a low risk of bias for adequate randomisation. Only randomised trials were included Limitations Findings were limited to the inclusion criteria of individual studies which varied in the definition of GDM, duration, intensity and frequency of intervention.

Author and Year	Study Design	Objectives	Sample Size	Interventions	Results	Limitations and Strengths
					one trial each and showed a beneficial effect. The risk of GDM was reduced in obese and overweight pregnant women for GDM (RR 0.40, 955 CI 0.18, 0.86).	Different criteria for defining GDM may have changed estimates of effect.
Zhang et al., 2014	Prospective cohort study	To quantify the association between a combination of healthy factors before pregnancy (healthy body weight, healthy diet, regular exercise, and not smoking) and the risk of gestational	20136 singleton live births in 14437 women without chronic disease. Exclusion criteria: Pregnancies after previous GDM	Low-risk factors for GDM development including not smoking, healthy eating and physical activity.	Each lifestyle factor measured was independently and significantly associated with the risk of gestational diabetes. The combination of three risk actors (non-smoker, ≥150 minutes a week of moderate to vigorous physical activity, and healthy eating (top two-fifths of Alternate Healthy Eating Index-2010 adherence score)) was associated with a 41% lower risk of gestational diabetes compared with all	Strengths: A large prospective cohort study. Self-reported GDM diagnosis was validated by medical records. The outcomes were controlled for well-documented risk factors to avoid confounding. A well-validated questionnaire was used. Limitations: Measurement error in self-reported variables. The number of cases in the cohort

Author and Year	Study Design	Objectives	Sample Size	Interventions	Results	Limitations and Strengths
					other pregnancies (relative risk 0.59, 95% CI 0.48 to 0.71.	might have been slightly overestimated due to over-reporting of GDM.
Viana, Gross, & Azevedo, 2014 (Viana et al., 2014)	Systematic review literature search through March 2014	To analyse the efficacy of dietary interventions on maternal or new-born outcomes in patients with GDM.	9 trials were included with 884 pregnant women. Inclusion criteria: RCTs that evaluated the effect of dietary intervention on patients diagnosed with GDM or glucose intolerance or hyperglycaemia with reported maternal and new-born outcomes were included. Dietary interventions must have lasted for at least 4 weeks and continued until delivery. Exclusion criteria: Studies that were not randomized, included patients with type 1 or 2 diabetes, had the same dietary interventions in all studied groups, lacked dietary	Low glycaemic index diet (n=4; 257 patients) Total energy restriction diet (n=2; 425 patients) Low carbohydrate diet (n=2; 182 patients) Others (n=1; 20 patients	Diet with low glycaemic index reduced the proportion of patients who used insulin (relative risk 0.767 [95% CI 0.597, 0.986]; P=0.039) and the new-born birth weight (weight mean differences -161.9 g [95% CI -246.4, -77.4]; P=0.000) as compared with control diet. Total restrictions and low carbohydrate diets did not change either maternal or new-born outcomes.	Limitations: Different diagnostic criteria for GDM were used in the included studies. A small number of studies were included in each dietary intervention category analysis.

Author and Year	Study Design	Objectives	Sample Size	Interventions	Results	Limitations and Strengths
			characteristics or did not report any of the outcomes of interest were excluded.			
Bain et al. (2015)	Systematic review literature review such before February 2015	To assess the effects of combined diet and exercise interventions for preventing GDM and associated adverse health consequences for women and their babies.	13 random ised controlled trials with 4983 women and their babies were included. Inclusion criteria: Pregnant women regardless of age, gestation, parity or plurality. Exclusion criteria: Studies involving women with pre-existing type I or type II diabetes.	Interventions that incorporated any type of dietary advice with any type of exercise interventions were included. Studies that compared dietary advice and exercise interventions were compared with no intervention (standard care).	There was no clear difference in the risk of developing GDM (average risk ratio (RR) 0.92, 95% CI 0.68-1.23; 11 trials, 3744 women), caesarean section (RR 0.92, 95% CI 0.83-1.01; 7 trials, 3246 women), or large for gestational age (RR O.90, 95% CI 0.77 to 1.05; 2950 infants.	Strengths: At least two independent review authors participated in study selection, data extraction and bias assessment. Limitations: Recent studies and unpublished studies were not included.
Sabry et al. (2020) (Fatma A. Sabry1, 2020)	Case-control study	To evaluate the impact of an educational intervention for pregnant diabetic women on their awareness regarding diet and exercise.	100 individuals 50 cases and 50 controls Inclusion criteria: Women from 18-45 years. Women at the second trimester of pregnancy. Women have a blood glucose level more than normal. Exclusion criteria:	Education on diet and exercise intervention	No statistically significant difference between cases and controls according to their knowledge and practice about diet and exercise in pre-intervention. No significant difference in knowledge and	Limitation: Small sample size

Author and Year	Study Design	Objectives	Sample Size	Interventions	Results	Limitations and Strengths
			Women with any chronic or acute diseases as cardiac disease restrictive lung disease. Women with incompetent cervix or cerclage, multiple gestations at risk of preterm birth, persistent second or third trimester bleeding, placenta previa after 26 weeks gestation, preterm labour ruptures membranes, pre-eclampsia or pregnancy-induced hypertension, severe anaemia		practice about diet and exercise post-intervention.	
Gilbert et al., 2019	Integrative review study	To determine how diet, physical activity and psychosocial well-being interact in women with GDM	16 articles were included: 2 observational and 14 intervention studies Inclusion criteria: Observational or intervention studies in women with GDM that focused on at least 2 domains of interest.	Interventions that focused on lifestyle intervention (diet and exercise) and psychosocial well-being Were included in the review.	Lifestyle intervention improved diet quality in all studies and improvement of physical activity in half of the studies. There was better anthropometric and metabolic health outcome, decreased	Strengths: Comprehensive search strategy and independent reviewers. Large sample size. Limitations: Large heterogeneities regarding the

Author and Year	Study Design	Objectives	Sample Size	Interventions	Results	Limitations and Strengths
			Exclusion criteria: Excluded study protocols, conference abstracts, recommendation papers, guidelines, qualitative studies and review articles. Articles that exclusively investigate women with Type 1 and Type 2 diabetes were excluded. Intervention studies that only tested pharmacological interventions were excluded as well as genetic, epigenetic and genomic studies. Studies which focused on dietary supplement Animal research papers, papers addressing exclusively the microbiome were also excluded		preterm births and macrosomia, lower rates of progression to diabetes after birth.	interventions and follow-up periods as well as lifestyle interventions in the respective studies.

CHAPTER 3: Underlying, non-modifiable and intermediate risk factors for the development of Gestational Diabetes Mellitus, in Cape Town: A case-control study

Abstract: Gestational diabetes mellitus (GDM) is associated with complications to the mother and child during pregnancy as well as increased cardio-metabolic disease risk after pregnancy. This case-control study investigated the underlying, non-modifiable and intermediate risk factors for the development of GDM in women living in Cape Town. A questionnaire and medical record review were used to obtain data in the 167 cases and 199 controls. Mid- upper arm circumference (MUAC) (OR 1.17, 95% CI 1.04-1.31, p =0.008), family history of diabetes mellitus (OR 3.10, 95% CI 1.45-6.61, p =003) and stillbirth (OR 11.61, 95% CI 1.04-129.90, p =0.047) were associated with GDM risk. When MUAC was excluded from the model, BMI was significantly associated with GDM risk (OR 1.11, 95% CI 1.05-1.17, p <0.001). The optimum MUAC cut-off point for predicting GDM was 30.1cm, with a sensitivity of 84% and specificity of 59%. The BMI cut-off point for predicting GDM was 32.4 kilograms per meters squared (kg/m^2), with a sensitivity of 77% and a specificity of 68%. These findings are important in early screening for GDM to prevent its increasing prevalence and adverse effects.

Key Words: Gestational diabetes mellitus; non-modifiable risk factors; intermediate risk factors; underlying risk factors, Cape Town, South Africa.

3.1 INTRODUCTION

Gestational diabetes mellitus (GDM) is defined as any degree of glucose intolerance with onset or first recognition during pregnancy that is not clearly overt diabetes (ADA, 2020b). GDM is one of the most common complications of pregnancy and its global prevalence is estimated to be 16% (Guariguata et al., 2014). In Africa, two systematic reviews reported the prevalence of GDM to vary between 0-14% (Macaulay et al., 2018, Mwanri et al., 2015a, Shelley Macaulay1*, 2014) while, in South Africa, the GDM prevalence ranges from 9.1% in Soweto (Macaulay et al., 2018) to 25.8% in Johannesburg (Adam and Rheeder, 2017b). GDM has negative effects during pregnancy and on pregnancy outcomes such as macrosomia, preeclampsia and preterm birth (Wahabi et al., 2014), as well as long-term effects for the mother such as T2DM later in their lives (Chivese et al., 2019b).

One of the well-established risk factors for GDM globally is increasing maternal age, although the age cut-off suggested for screening for GDM may differ among countries (Lamminpää et al., 2016, Abu-Heija et al., 2017, Muche et al., 2019b). In Italy, Londero et al. (2019), found that giving birth after the age of 40 years increased the risk of gestational diabetes. Further, Abu-Heija et al. (2017), reported that women >35 years had a 14.7% GDM incidence when compared to women who were ≤25 years (2.2% GDM incidence) in a study conducted in Oman (Abu-Heija et al., 2017). Ethnicity is also one of the significant non-modifiable risk factors for GDM. A study conducted in the US found a higher GDM prevalence among Asian and Filipino women when compared to non-Hispanic white women and African American women, despite many of these women presenting with a lower BMI of 22.0-24.9 kg/m^2 (Hedderson et al., 2012).

Overweight and obesity before pregnancy and excessive weight gain during pregnancy not only increase the risk of GDM development but also have adverse effects on pregnancy outcomes (Miao et al., 2017). In a recent South African study, the increase in GDM was linked to a higher obesity prevalence in South Africa (Dias et al., 2019a). Moreover, the South African maternity guidelines recommend that mid-upper arm circumference (MUAC) ≥33cm in pregnancy should raise concerns about pregnancy-related complications such as GDM. Several studies have highlighted a family history of diabetes mellitus (DM) as one of the risk factors for GDM development (Erem et al., 2015b, Lee et al., 2018b, Muche et al., 2019b). Additionally, pregnant women with a history of GDM have a higher risk for GDM development in their subsequent pregnancies compared to women without a history of GDM (Khan et al., 2013a). In a systematic review, a family history of GDM was associated with 3.46 times increased risk of GDM development (Moosazadeh et al., 2017b). Therefore, GDM history is one of the most common risk factors that inform early GDM screening among pregnant women. Women who have had complications in their previous pregnancies such as macrosomia, preterm birth, congenital malformation, and caesarean births are at risk of developing GDM in their subsequent pregnancy/pregnancies (Dobjanschi and Miulescu, 2015).

The relationship between educational level and GDM risk as observed in previous studies are conflicting (Bouthoorn et al., 2015, Khan et al., 2013a, Rajesh Rajput, 2013). Bouthoorn et al. (2015), reported that women in the Netherlands with the lowest educational levels were three times more likely to develop GDM when compared to women with the highest educational level even after adjustments for ethnicity, age, family history of diabetes and parity was made (Bouthoorn et al., 2015). Khan et al. (2013b)(Rajput et al., 2013), however, found no significant association between GDM and the educational level of women in a study conducted in Pakistan. On the contrary, a study conducted in India showed that GDM risk increased with the higher educational level of women (Rajput et al., 2013). However, Rajput et al. (2013) findings could be explained by the presence of confounding factors such as age and BMI being higher in women who were more educated.

There is currently very little information on the risk factors for GDM in Africa including South Africa (Mwanri et al., 2015a). Mwanri et al. (2015a), in a systematic review of studies conducted in Africa found overweight, obesity, previous history of stillbirth, previous macrosomia, family history of Type 2 Diabetes Mellitus and age ≥30 years as GDM risk factors (Mwanri et al., 2015a). The systematic review highlighted the need for more studies in Africa since only 22 studies were included in the review. Moreover, there are no established cut-off points for risk factor-based GDM screening such as age, BMI, and MUAC, which are specific to South African women, especially those living in the Western Cape Province. Risk factor-based screening in the Western Cape is based on cut-off points from other populations. Understanding the risk factors for the development of GDM including cut-offs, early screening and the management thereof is important to reduce its prevalence and negative effects on both the mother and infant. Therefore, this study aims to investigate how underlying, non-modifiable, and intermediate risk factors (maternal age, ethnicity, educational level, economic status, GDM history, family history, previous macrosomia, medical history, pregnancy history, and weight history) affect the development of Gestational Diabetes Mellitus (GDM) in this specific target population.

3.2 METHODS

3.2.1 Study design and target population

The study conducted between 2011 and 2016 followed a case-control study design. The target population was pregnant women, 18 years and above, without pre-existing diabetes; Type 1 Diabetes Mellitus, or Type 2 Diabetes Mellitus (T1DM or T2DM), attending two public health care facilities in Cape Town, Western Cape Province, South Africa. Cases were women, diagnosed with GDM and controls were pregnant women without diagnosed GDM from the same community. Cases were diagnosed using the Western Cape diagnostic criteria which includes one or more of the following criteria: fasting blood glucose of ≥5.6mmol/l and/or ≥7.8 mmol/l two hours 75g post glucose load in 2011. The Society of Endocrinology, Metabolism and Diabetes of South Africa (SEMDSA) has adopted the WHO 2013 GDM screening guidelines which are: fasting blood glucose of 5.1-6.9 mmol/l, and/or ≥10 mmol/l at 1 hour, and/or 8.5-11 mmol/l at 2-hours post a 75g oral glucose load (Singh et al., 2017). Women were included if they were above 24 weeks gestation to ensure that women with undiagnosed pre-existing DM have been screened and diagnosed. On the other hand, women were excluded if they were below 24 weeks gestation and if they had DM before pregnancy. Cases and controls were matched for ethnicity to ensure accuracy in data interpretation and to minimise confounding factors.

3.2.2 Sample size

The sample size was calculated based on the ability to detect an odds ratio of at least 1.5 in any one of the binary risk factors (family history of DM or stillbirth) assuming at least 20% more cases had these exposures, compared to controls. Using the OpenEpi sample size calculator (Sullivan et al., 2009), a minimum power of 80% at a significance level of 5%, a sample size of 167 cases and 199 controls were estimated. More controls were recruited to increase power. Post hoc power analysis showed that the study had sufficient power to detect significant differences in BMI, mid-upper arm circumference (MUAC), maternal age, and family history of GDM.

3.2.3 Recruitment

In South Africa, women with GDM are treated in tertiary healthcare facilities. Therefore, we recruited cases from a tertiary healthcare facility and controls from a primary healthcare facility. In the Cape Town metropolitan (Western Cape Province of SA), women diagnosed with GDM at primary health care facilities are referred to tertiary hospitals (Groote Schuur Hospital and Tygerberg Hospital) or secondary hospitals (Mowbray Maternity Hospital (MMH) and Somerset hospital), depending on which geographical area they reside in. We recruited cases from Groote Schuur Hospital (GSH). Controls were recruited from the antenatal clinic at Vanguard Community Health Centre (CHC), which is a primary-level public health care facility. Both Vanguard CHC and GSH are situated in the Cape Town Southern health district. The participants were recruited when attending the antenatal clinic for their routine appointment as follows: the fieldworker approached women in the waiting areas and invited them to an explanation of the study information and expectations in a separate room and asked if they were interested in participating in the study. Written consent was obtained from the participants before the interviews. Over the total study period, 16 potential controls and 7 potential cases did not agree to participate in the study due to a lack of time. Women with GDM who had been admitted to the GSH maternity unit were approached individually at their bedside. All participants were recruited based on consecutive sampling.

3.2.4 Ethics approval

Ethical approval for this study was obtained from the University of Cape Town, Faculty of Health Sciences, Human Research Ethics Committee (reference number: 111/2011 and 113/2011)(ref no.). Institutional permission was obtained from the Western Cape, Department of Health, the chief operational officer of GSH and the facility manager at the Community Health Centre. The participants were recruited voluntarily and provided informed consent before the commencement of their participation in the study.

3.2.5 Data Sources/ Measurement

3.2.5.1 Questionnaire

A fieldworker interviewed each participant on recruitment using a questionnaire developed for this study. The development of the questionnaire involved a literature search on risk factors for GDM, formulation of a dendogram of all relevant factors, and discussions on the drafted questions by an expert panel. Before the start of the study, questionnaires were translated in Africans and isiXhosa and back translated to English. A pilot study with 10 participants from both GSH and Vanguard CHC was conducted before its finalisation to ensure face and content validity. The field workers were final-year dietetic students of the University of Cape Town and registered dietitians (RD), who were all trained and standardized in the consent process and data collection procedures. The interviews were conducted in the waiting room or beside the participants' beds, for cases who were admitted at GSH. The questionnaire included questions on socio-demographic characteristics, anthropometric, medical and pregnancy information and the weight history of the participants. Socio-demographic information included questions on age, ethnicity (Black, Mixed ethnicity and Asian), country of origin, educational status (none/primary, secondary and tertiary), marital status (married/living with a partner and single/divorced/widowed), type of housing the participants lived in, employment status, whether or not participants were recipients of social grants (Yes/ No) and the number of dependents. Medical history information on the diagnoses of hypertension and preeclampsia were obtained from the participants' medical file. Information on pregnancy history obtained from the participants using the questionnaire included parity, previous birth weights and whether previous births were preterm or term, number of miscarriages, live births and number of stillbirths. Previous GDM history and family history of DM (T1DM, T2DM and GDM) were also included in the questionnaire.

Participants were asked about their perception of their weight status at different life cycle stages; birth weight, when they were <13 years old, 13-18 years old, 18-25 years old, 25-30 years old and just before their current pregnancy, given the following answer options: either too thin (underweight), just about right (normal weight) or too chubby/fat (overweight). Additionally, they were asked to indicate their perceived weight gain in their current pregnancy as either not enough, normal or too much. The questionnaire took about 15 to 20 minutes to complete.

3.2.5.2 Anthropometric assessment

Anthropometric assessments (height and current weight) are routinely measured and recorded by the nursing staff at these facilities and were obtained from the participants' medical files by the field worker. The pre-pregnancy weight was either obtained from the participant's folder or by the patient's recall at the interview if this information was missing from the participant's medical folder. Both the pre-pregnancy and pregnancy BMI were calculated using the equation of weight divided by height squared (Use et al., 1995). Although BMI cannot be classified in pregnancy, we compared it between cases and controls as an index of weight. The trained fieldworkers measured the participants' MUAC in centimeters (cm) on the left upper arm, perpendicular to the midway between the tip of the shoulder and the tip of the elbow, while the elbow was extended. A MUAC tape measure was used and measurements were taken once.

MUAC is used to assess nutritional status. According to SEMDSA, MUAC above 30 centimeters (cm) for pregnant women should raise health concerns (Webb, 2018)

3.2.5.3 Statistical analysis

Data were managed in Microsoft Excel before being exported to Stata 15 (Stata Corporation, 2016) for all statistical analyses. A statistical significance of $p<0.05$ was used, and 95% CIs were reported for estimates, where appropriate.

Continuous data were tested for normality using histograms. For descriptive purposes, frequencies and percentages were calculated for categorical variables, while means and standard deviations (SDs) were calculated for continuous data with a normal distribution. For non-normal continuous data, both means and SDs and medians and interquartile ranges (IQRs) have been calculated where appropriate and are displayed in the form of tables. This was done as the median values were often not sufficiently descriptive to interpret and describe the significant differences between cases and controls. To compare the risk factor variables between cases and controls, the Pearsons Chi² test was used for categorical variables and independent sample T-test or Wilcoxon rank sum test, as appropriate, for continuous variables.

To evaluate associations between the potential risk factors for GDM a binary variable (cases coded "1", controls coded "0"), logistic regression was used. Variables that were significantly different between cases and controls are known to be associated with GDM, as evidenced by a review of the literature, and were included in the logistic regression models. These variables included age, BMI, MUAC, gravida, stillbirth, and family history of DM. Variables with missing data >10%, were not included in the multivariate analysis (previous birth weights, weight gain history in previous pregnancies).

Model testing and diagnostics included checking for multicollinearity (all variance inflation factors were less than two i.e. <2, suggesting no concerns for multicollinearity), model specification (the link function was correctly specified since hatsq (p =0.510) was not statistically significant), Hosmer Lemeshow goodness of fit test showed that the data fit the logistic model (p=0.681), Linearity assumption between the log odds of GDM and the covariates (the Lowess graph showed reasonable fit), as well as checking for influential cases.

Additionally, we estimated the optimal cut-off points for the diagnosis of GDM for age, BMI and MUAC, using the cut-point module in STATA. We used the default Liu (Liu, 2012) method that maximises both sensitivity and specificity. We reported specificity and sensitivity for each cut-off point.

3.3 RESULTS

3.3.1 Socio-demographic characteristics

The total number of participants was 366, of which 167 (45.6 %) were cases and 199 (54.4 %) were controls. The mean age of cases was significantly higher than that of controls, [32.5(28.0-37.0) years versus 25 (22.0-31.0) years respectively, $p<0.001$]. However, after matching for age, there was no significant difference between cases and controls. There was no significant difference in ethnicity between cases and controls, before and after matching for age (Table 3.1).

The majority of the total sample completed secondary-level education (83.3%), 38.6% were employed and 35.1% received a social grant, with no significant differences in these variables between cases and controls. Significantly more cases were married or lived with their partner and lived in households with a fewer number of adults and a lower number of other household members being employed than the controls (Table 3.1). However, there were no significant differences after matching for age (Table 3.1).

Table 3.1 Comparison of socio-demographic factors between cases and controls

	Unmatched				**Matched for age**			
Socio-demographic	Total, n=366	Cases, n=167	Controls, n=199	P-value	Total n=208	Cases, n=104	Controls N=104	P-value
Age, median (IQR)	28 (24.0-34.0)	32.5 (28.0-37.0)	25.0 (22.0-31.0)	<0.001[e]	206 30.0 (27.0-34.0)	103 30.0 (27.0-34.0)	103 30.0 (26.0-34.0)	0.737 [e]
Ethnicity, n (%)								0.576 [d]
Black	179 (48.6)	81 (47.9)	98 (49.3)	0.449[d]	97(46.6)	47(22.6)	50(24.0)	
Mixed[a]	180 (48.9)	82 (48.5)	98 (49.3)		107(51.4)	54(26.0)	53(25.5)	
Asian	9 (2.5)	6 (3.6)	3 (1.5)		4(1,9)	3(1.4)	1(0.5)	
Education level, n (%)								0.608 [d]
None/primary	15 (4.1)	7 (4.2)	8 (4.0)	0.082[d]	10(4.8)	4(1.9)	6(2.9)	
Secondary	305 (83.3)	132 (79.0)	173 (86.9)		170(81.7)	84(40.4)	86(41.4)	
Tertiary	46 (12.6)	28 (16.8)	18 (9.1)		28(13.5)	16(7.7)	12(5.8)	
Marital status, n (%)								
Married/living with partner	227 (62.0)	119 (71.3)	108 (54.3)	0.001[d]	70(33.7)	31(14.9)	39(18.8)	0.240 [d]
Single/divorced/widowed	139 (38.0)	48 (28.7)	91 (45.7)		138(66.4)	73(35.1)	65(31.3)	
No of adults in the household, Median (IQR)	2.0 (1.0-3.0)	2.0(1.0-2.0)	2.0 (1.0-3.0)	0.023[e]	208 2.0 (1.0-2.0)	104 2.0 (1.0-2.0)	104 1.5 (1.0-3.0)	0.751 [e]
Mean-SD	2.1 (1.5)	1.8 (1.1)	2.3 (1.7)		2.0 (1.4)	1.9 (1.1)	2.1 (1.6)	
Employed, n (% yes)	142 (38.6)	64 (37.9)	78 (39.2)	0.795[d]	0.354	35 (16.8)	47 (22.6)	0.089 [d]
Others employed in household, Median (IQR)	1.0 (1.0-2.0)	1.0 (1.0-1.0)	1.0 (1.0-2.0)	0.004[e]	205 2.0 (1.0-3.0)	102 1.0 (1.0-1.0)	103 1.0 (1.0-2.0)	0.813 [e]
Mean-SD	1.2 (1.0)	1.1 (0.7)	1.4 (1.2)		2.0 (1.4)	1.2 (0.7)	1.2 (0.9)	
Social grant[b] recipient, n (% yes)	129 (35.1)	62 (36.7)	67 (33.7)	0.545[d]	79(38.0)	36(17.3)	43(20.7)	0.320 [d]

[a] Mixed race-ancestry are also known as Cape Coloureds, a population in Cape Town, South Africa with mixed genetics from Khoisan, African Bantu, Northern European and South Asia. [b] Social grants are monthly grants paid by the South African government to SA citizens that meet a specific criteria and include pension, child support, disability, care-dependency and foster care grants. [d] Chi-squared test. [e] Wilcoxon rank-sum test (non-normal data).

3.3.2 Medical and pregnancy history

The gestational age at recruitment of cases and controls was similar (Table 3.2), however, cases had significantly higher gestational age after matching for age. Cases had a significantly higher number of previous pregnancies, live births, miscarriages and stillbirths compared to controls (Table 3.2). These significant differences disappeared after matching for age. A significantly higher proportion of cases had GDM in a previous pregnancy, hypertension and preeclampsia in the current pregnancy and a family history of DM and GDM compared to controls (Table 3.2). These differences remained significant after matching age. Results applicable to cases only indicate that 53.2% (n=59) were currently treated with oral hypoglycaemic tablets, 13.5% (n=15) with insulin, 13.1% (n=15) with both insulin and oral tablets and 19.8% (n=22) did not receive any pharmacological treatment.

Table 3.2 Comparison of Medical and Pregnancy History between Cases and Controls

	Unmatched					Matched for age		
Medical and pregnancy history	Cases, n=167		Controls, n=199		P-value	Cases, n=104	Controls n=104	P-value
	n	Median (IQR)	n	Median (IQR)		N median(IQR)	N median(IQR) Mean-SD	
Gestational age	167	33.0 (29.0-36.0)	199	32.0 (28.0-36.0)	0.178[b]	104 34.0 (30.0-36.0)	104 31.5 (28.0-36.0)	0.031[b]
Number of pregnancies median (IQR)	167	3.0 (2.0-4.0)	199	2.0 (1.0-3.0)	<0.001[b]	104 3.0 (2.0-4.0)	104 2.0 (2.0-3.0)	0.115[b]
Number of miscarriages Median (IQR)	165	0.0 (0.0-1.0)	198	0.0 (0.0-0.0)	0.001[b]	103 0.0 (0.0-1.0)	104 0.0 (0.0-0.0)	0.119[b]
Number of live births Median (IQR)	162	2.0 (1.0-2.0)	197	1.0 (0-1.0)	<0.001[b]	101 1.0 (0.0-2.0)	103 1.0 (1.0-2.0)	0.615[b]
Stillbirth Median (IQR)	165	2 (0.0-0.0)	197	1.0 (0.0-0.0)	0.001[b]	102 0.0 (0.0-0.0)	103 0.0 (0.0-0.0)	0.396[b]
	n	% Yes	n	% Yes	P-value	N(%yes)	N(%yes)	P-value
GDM in a previous pregnancy	40	28.6	1	0.6	<0.001[a]	22(12.4)	1(0.6)	<0.001[a]
Hypertension in current pregnancy	49	29.0	13	6.5	<0.001[a]	26(12.5)	9(4.3)	0.002[a]
Preeclampsia in current pregnancy	14	8.3	1	0.5	<0.001[a]	8(3.9)	0(0)	0.004[a]
Family members with diabetes	84	50.6	41	20.7	<0.001[a]	58(28.0)	28(13.5)	<0.001[a]
Family members with GDM	22	13.8	6	3.0	<0.001[a]	14(6.9)	3(1.5)	0.004[a]

[a] Chi-squared test. [b] Wilcoxon rank-sum test (non-normal data). [c] Independent *t*–test (normally distributed data).

3.3.3 Weight history

As seen in Table 3.3, cases had significantly higher current weight, BMI, MUAC and pre-pregnancy weight compared to controls. Additionally, a significantly higher proportion of cases compared to controls thought they were overweight before pregnancy (47.3% versus 17.6%, p <0.001) and that they had gained too much weight during the current pregnancy (39.8% versus

21.6%, p <0.001). There were significant differences between cases and controls for the perception of their weight status during their childhood, adolescence and young adulthood years. A higher percentage of cases compared to controls thought they were underweight or overweight during all these life cycle stages while more controls thought they were normal weight during these life cycle stages. However, between the ages of 25-30 years, more cases thought they were overweight when compared to controls (Table 3.3). The differences remained significant after matching for age.

Table 3.3 Comparison of Weight History between Cases and Controls

	Unmatched					**Matched for age**		
Weight history of participants		**Cases, n=167**		**Controls, n=199**	**P-value**	**Cases, n=104**	**Controls, n=104**	**P-value**
	n	**Median (IQR)**	**n**	**Median (IQR)**		**N median(IQR)**	**N Median(IQR)**	
Current BMI	163	35.9 (31.2-41.2)	199	29.3 (26.0-33.6)	**<0.001**[b]	104 35.7 (31.4-41.3)	104 29.6 (26.5-34.1)	**<0.001** [b]
Pre-pregnancy BMI	156	32.0 (28.0-37.3)	169	25.8 (21.6-30.1)	**<0.001**[b]	101 31.5 (27.3-37.7)	91 25.9(22.4-30.4)	**<0.001** [b]
Mid-Upper Arm Circumference (MUAC)	153	34.5 (31.0-37.3)	181	29.0 (25.7-31.5)	**<0.001**[b]	104 33.6 (31.3-36.0)	104 29.2 (26.0-31.8)	**<0.001** [b]
Perception of pre-pregnancy weight	**n**	**% Yes**	**n**	**%Yes**	**P-value**	**N(%Yes)**	**N(%Yes)**	**P-value**
Underweight	4	2.4	17	8.6	**<0.001**[a]	4(1.9)	9(4.3)	<0.001 [a]
Normal weight	84	50.3	147	73.9		55(26.4)	79(38.0)	
Overweight	79	47.3	35	17.6		45(21.6)	16(7.7)	
Perception of weight gained during current pregnancy	**n**	**%Yes**	**n**	**%Yes**	**P-value**	**N(%Yes)**	**N(%Yes)**	**P-value**
Not enough	21	12.7	35	17.6	**0.001**[a]	16(7.7)	18(8.7)	0.001 [a]
Just right	79	47.6	121	60.8		43(20.8)	66(31.9)	
Too much	66	39.8	43	21.6		44(21.3)	29(9.7)	
	n	Median (IQR)	N	Median(IQR)	**P-value**	**N Median (IQR)**	**N Median (IQR)**	**P-value**
Self-reported weight gain during current pregnancy, median(IQR)	158	9.0 (4.0-14.0)	169	8.0 (4.0-11.0)	**0.102**[b]	10.0 (5.0-15.0)	7.5 (4.0-10.5)	0.058 [b]
Perception of weight when participants were: n % <13 years, n %	**n**	**%Yes**	**n**	**%Yes**	**P-value**	**N(%Yes)**	**N(%yes)**	**P-value**
Underweight	48	28.7	32	16.1	**0.001**[a]	27(13.0)	17(8.2)	0.022 [a]

	Unmatched					Matched for age		
Normal weight	86	51.5	140	70.4		57(27.4)	76(36.5)	
Overweight	33	19.8	27	13.6		20(9.6)	11(5.3)	
13-18 years, n%	**n**	**%Yes**	**n**	**%Yes**	**p-value**	**N(%Yes)**	**N(%Yes)**	**P-value**
Underweight	34	20.4	17	8.5	**0.003**[a]	**21(10.1)**	**8(3.9)**	**0.016** [a]
Normal weight	101	60.5	147	73.9		61(29.3)	78(37.5)	
Overweight	32	19.2	35	17.6		22(10.6)	18(8.7)	
18-25 years, n%	**n**	**%Yes**	**n**	**%Yes**		**N(%Yes)**	**N(%Yes)**	**P-value**
Underweight	17	10.2	11	5.6	**0.005**[a]	**11(5.3)**	**1(0.5)**	**0.001** [a]
Normal weight	95	56.9	143	73.0		58(28.2)	78(37.9)	
Overweight	55	32.9	42	21.4		35(17.0)	23(11.2)	
25-30 years, n%	**n**	**%Yes**	**n**	**%Yes**		**N(%Yes)**	**N(%Yes)**	**0.006** [a]
Underweight	4	2.7	7	6.3	**<0.001**[a]	**4(2.1)**	**4(2.1)**	
Normal weight	66	43.7	74	66.1		40(20.8)	54(28.1)	
Overweight	81	53.6	31	27.7		44(23.0)	24(12.5)	

[a] Chi-squared test. [b] Wilcoxon rank-sum test (non-normal data).

3.3.4 Multivariable logistic regression for underlying risk factors for GDM

After logistic regression, the following were significantly associated with GDM (Table 3.4): MUAC (OR 1.17, 95% CI 1.04-1.31, p =0.008), family history of DM (OR 3.10, 95% CI 1.45-6.61, p=0.003) and stillbirth (OR 11.61, 95% CI 1.04-129.90, p =0.047).

BMI was not significantly associated with the risk of GDM when included in the same model with MUAC. However, when MUAC was removed from the model, BMI was independently associated with the risk of GDM (OR 1.11, 95% CI 1.05-1.17, p <0.001) (Table 3.4, Model 2). Moreover, when MUAC alone was included in the model, it was significantly associated with GDM risk (OR 1.20, 95% CI 1.11-1.30, p<0.001) (Table 3.4, Model 3).

The optimum cut-off point for predicting GDM was 30.1cm for MUAC, with a sensitivity of 84%, a specificity of 59% and an AUR of 71%. The cut-off point for BMI during pregnancy for predicting GDM was 32.4 (kg/$m^{2)}$, with a sensitivity of 68%, a specificity of 68% and an AUR of 68%.

Table 3.4 Multivariable logistic regression for underlying risk factors for GDM

Variable	**Model 1**			**Model 2**			**Model 3**		
	AOR[a]	**95% CI**	**P-value**	**AOR[a]**	**95% CI**	**P-value**	**AOR[a]**	**95% CI**	**P-value**
Age	0.96	0.89-1.04	0.350	0.97	0.89-1.05	0.414	0.96	0.88-1.04	0.322
Ethnicity (Mixed race)	1.07	0.51-2.26	0.086	1.01	0.49-2.10	0.974	1.05	0.50-2.20	0.906
Education (secondary)	2.13	0.25-18.22	0.489	1.13	0.19-6.67	0.889	2.45	0.29-21.08	0.413
Education (tertiary)	4.16	0.41-42.13	0.227	2.41	0.34-17.06	0.378	4.66	0.45-48.22	0.196
Marital status (single/widowed)	0.72	0.34-1.56	0.407	0.67	0.32-1.42	0.296	0.73	0.34-1.57	0.420
Gestational age	1.06	0.98-1.14	0.149	1.06	0.99-1.15	0.105	1.06	0.98-1.14	0.148
Social grant[b] recipient, n (% yes)	0.93	0.43-2.00	0.853	1.01	0.48-2.13	0.980	0.90	0.42-1.92	0.791
BMI	1.02	O.95-1.12	0.548	1.11	1.05-1.17	<0.001	-	-	-
MUAC	1.17	1.04-1.31	0.008	-	-	-	1.20	1.11-1.30	<0.001
Stillbirth	11.61	1.04-129.90	0.047	11.02	0.98-123.48	0.052	11.32	1.02-125.64	0.048
Family history of DM	3.10	1.45-6.61	0.003	3.14	1.50-6.59	0.002	3.12	1.47-6.65	0.003
Hypertension	2.45	0.89-6.76	0.083	2.64	0.98-7.16	0.056	2.45	0.89-6.68	0.084
Family history GDM	2.97	0.65-13.48	0.159	3.58	0.81-15.84	0.093	2.87	0.64-12.98	0.170

[a] AOR-Adjusted Odd Ratios *Multivariable analysis 1 (model 1) has both BMI and MUAC included in the analysis, model 2 has BMI only while model 3 has MUAC only.

3.4 DISCUSSION

In this case-control study, we found that high MUAC, BMI, a family history of DM and a history of stillbirth were all independently associated with the risk of GDM in women receiving antenatal care in the public sector in Cape Town, South Africa.

The results of our study showed that more cases were older compared to controls before matching for age in the univariate analysis. Although we did not investigate age as a risk factor for GDM, as this was linked to the sampling in the current study, studies conducted in Africa have reported age as a risk factor for GDM (Shelley Macaulay1*, 2014, Dias et al., 2019a, Adoyo et al., 2016). Moreover, a recent systematic review with over 120 million participants reported a linear increase in GDM with successive age groups, the highest risk being among women ≥40 years (Li et al., 2020b).

In the current study, cases had a significantly higher family history of DM compared to controls before and after matching for age in the univariate analysis. Moreover, participants with a family history of DM were 3.2 times more likely to have GDM when matched with controls. Our finding is consistent with the findings of other studies in Africa by Muche et al. (2019a) (OR 2.69) Macaulay et al. (2018) and Natamba el al. (2019) (OR 1.79) (Muche et al., 2019a, Macaulay et al., 2018, Natamba et al., 2019). Other studies outside Africa reported by Erem et al. (2015b) (OR 4.5) and Lee et al. (2018b) (OR 2.77) conducted in Turkey and Asia respectively, support our findings in this regard. (Erem et al., 2015b, Muche et al., 2019b, Lee et al., 2018b). We did not find an association between a family history of GDM and GDM risk. Our findings are consistent with studies conducted by Fawole et al. (2014) (OR 1.25) and Erem et al. (2015b) (OR 0.05) in Nigeria and Turkey respectively (Fawole et al., 2014, Erem et al., 2015b). However, Lee et al. (2018b) found a 3.5 increased risk of GDM development with a family history of GDM in a systematic review in Asia. The relationship between a family history of GDM with increased risk of GDM is associated with both genetic and lifestyle factors (Retnakaran et al., 2007). Therefore, pregnant women with a family history of diabetes mellitus should be educated early enough about the measures and precautions to prevent GDM.

Moreover, when BMI alone without MUAC was included in the logistic regression, it was significantly associated with GDM risk (OR 1.12, p<0.001), in keeping with previous studies in Africa (Muche et al., 2019b, Macaulay et al., 2018), China (OR 1.95, p<0.001) (Miao et al., 2017) and Mexico (OR 1.95, p<0.001) (Bautista-Castano et al., 2013). Obesity reduces insulin sensitivity, which possibly explains the relationship between obesity and GDM risk. This happens because over-nutrition affects the body's ability to maintain blood sugar at the right level, leading to a reduction of insulin sensitivity. The increasing prevalence of obesity in South Africa is likely to lead to a future increase in GDM prevalence (Dias et al., 2019a). Although we have used BMI to compare cases and controls, it is known that BMI cannot be used to classify pregnant women as overweight or obese in research and clinical practice (Fakier, 2015).

Among the anthropometric markers, MUAC and BMI all showed strong associations with GDM. As expected, MUAC showed a strong association with GDM with an OR of 1.2 and was a good predictor of GDM risk with 84% sensitivity and 59% specificity. BMI had a 68%

sensitivity and 68 % specificity. Furthermore, the optimum cut-off point for MUAC in predicting GDM was ≥30.1cm. This is higher than a Tanzanian study that reported MUAC ≥28cm as one of the risk factors for GDM (Nombo et al., 2018). Guidelines for maternity care in South Africa support the use of MUAC instead of BMI in determining pregnancy weight status (Fakier, 2015). Measuring MUAC is simpler, does not require the use of expensive equipment or calculations, and does not change significantly during pregnancy when compared to weight (Fakier, 2015). However, it is not common practice at GSH that MUAC measurements are taken during antenatal clinics by clinicians. According to SA maternity guidelines, MUAC ≥33cm is associated with obesity and should raise concerns about GDM and other pregnancy-related complications (Fakier, 2015). Moreover, MUAC should be used routinely and clinicians should be properly trained to ensure accuracy in measuring MUAC.

The BMI cut-off points for prediction of GDM in our study (BMI ≥32.4 kg/m^2 with 68% sensitivity and 68% specificity) differ from the current cut-off points used in Cape Town for risk factor-based selective GDM screening (BMI ≥40kg/m^2), although these have not been validated. Additionally, our findings on the MUAC cut-off for predicting GDM (≥30.1 cm with a sensitivity of 84% and 59% specificity) are lower than that included in guidelines for maternity care in South Africa (SA) (≥33.0 cm). Thus, it is likely that many women with GDM in Cape Town and the Western Cape Province are not being diagnosed due to the higher BMI cut-offs in the risk factor-based selective screening currently used. Due to the negative pregnancy outcomes of GDM for both the mother and infant (Chivese et al., 2019b), it may be advisable to incorporate these lower cut-offs into the selective screening program. Notably, lifestyle interventions focused on diet and physical activity both before and during pregnancy to prevent overweight and obesity in women at risk will help reduce the increasing prevalence of GDM.

In the current study, cases had a significantly higher number of stillbirths and miscarriages, which disappeared after matching for age in the univariate analysis. In the multivariable analysis, a history of stillbirth was associated with GDM. Our study finding is consistent with studies by Mwanri et al. (2014), (OR 2.8), conducted in Tanzania and Fawole et al. (2014), (OR 3.13), in Nigeria. On the contrary, Ali et al. (2016), and Rosenstein et al. (2012), did not find an increased risk of GDM with a previous history of stillbirth. Cases had a significantly higher number of pregnancies and live births when compared to controls in the univariate analysis. However, gravida was not significantly associated with GDM risk (OR 1.01, p=0.938) in our study. Moreover, previous preterm births were also significantly higher among cases when compared to controls in our study, but not associated with GDM risk. Contrary to our findings, a study conducted in France reported a link between preterm births and GDM (Mayor, 2017).

A greater proportion of the cases reported being married/living with a partner and living in households with fewer adults. However, the significance disappeared when matched for age in the univariate analysis. Moreover, being married/living with a partner was not found to increase GDM risk in the multivariate analysis. Rajput et al. (2013), in a study conducted in India, found no association between household income and GDM risk but found an increased risk of GDM with higher educational status(Rajput et al., 2013). On the other hand, Begum et al. (2017) in a study conducted in Bangladesh, found an increased GDM risk with higher income and higher educational status (Begum et al., 2017). However, studies conducted in the Netherlands (Bouthoorn et al., 2015), and India (Arora et al., 2015) found an inverse association between higher educational status and GDM risk. Rajput et al. (2013) explain that their observation could be linked to the advanced maternal age for women with higher education.

Women with GDM, experience complications in pregnancy including hypertension, preeclampsia, and cesarean sections (Ovesen et al., 2015). In our study, more cases experienced hypertension and preeclampsia during pregnancy when compared to controls Although some studies (Lee et al., 2017b, Lee et al., 2018a, Ottanelli et al., 2020) found an increase in GDM risk with a history of hypertension and preeclampsia, both coexist in pregnancies and increases the risk of developing cardiovascular diseases in future (Lee et al., 2017b, Ottanelli et al., 2020, Sandsæter et al., 2019). Early lifestyle modifications should be implemented to prevent negative pregnancy outcomes due to GDM.

3.5 STUDY LIMITATIONS AND STRENGTHS

One of the strengths of this study was that the field workers were well-trained and standardised on data collection tools, procedures and measurements to ensure the accuracy of the data collected. Also, the interviews were conducted in the participant’s language of choice and this allowed field workers to clarify questions during the interview. The limitations included potential recall imprecision as participants were asked to recall their pre-pregnancy weight and previous birth weights of their offspring. Self-reported data may also not be accurate and relying on clinic-recorded anthropometry does not guarantee accuracy. Furthermore, the cases were significantly older and had more previous pregnancies than the controls, although this was mitigated by matching and adjustment for age. However, the women who participated in the study are characteristic of women attending public antenatal care clinics in Cape Town.

3.6 CONCLUSION

This study has not only identified increasing high MUAC, family history of DM and stillbirth to be the risk factors for GDM development among women living in Cape Town, it has also generated specific cut-off points for MUAC and BMI. These need to be confirmed in other settings, both within SA and the rest of Sub-Saharan Africa as there is an urgent need to develop, test and implement selective GDM screening regimes on the continent where universal screening is unaffordable. In the meantime, the modifiable risk factors for GDM that we have identified can be used to counsel women before pregnancy and thus potentially reduce the short and long-term impact of GDM.

CHAPTER 4: Comparison of lifestyle factors between women with gestational diabetes mellitus and those without: A case-control study

Abstract

Background

As part of the management of Gestational Diabetes Mellitus (GDM), women receive counseling about lifestyle changes, to improve blood glucose control and reduce the risk of adverse events from the pregnancy. However, it is not known whether this advice translates to real changes in lifestyle factors during pregnancy in women with GDM. Therefore, we aimed to compare lifestyle factors between women with GDM and those without.

Methods

We performed a case-control study of 167 pregnant women with GDM (cases) and 199 pregnant women without GDM (controls) matched for ethnicity and gestational age. Eligible cases included pregnant women aged above 18 years with GDM who were ≥24 weeks of gestation attending Groote Schuur Hospital-GSH in South Africa. The control group consisted of pregnant women aged above 18 years attending antenatal clinics at the Community Health Centre (CHC), who had no GDM and were ≥24 weeks of gestation between 2011 and 2017. Lifestyle factors including physical activity, substance use, eating behaviour; uncontrolled eating scale and emotional eating scale, cravings, eating pattern, dietary intake, and household food security were assessed using a closed-ended questionnaire.

Results

We enrolled 389 participants in this study. In the analysis, women with GDM and those without GDM were similar concerning ethnicity, smoking history, gestational age, and food security. Median age differed significantly between women with GDM and those without GDM (32.5 vs. 25; $p<0.001$). After controlling for age, MUAC, gravida and gestational age, women with GDM were more likely to have low-fat foods (OR 1.06, 95% CI 1.02-1.10, p=0.003) and high fibre carbohydrates (OR 1.07, 95% CI 1.01-1.12, p=0.011), while they were less likely to have added sugar (OR 0.94, 95% CI 0.90-0.98, p=0.001) and energy-dense snacks (OR 0.91, 95% CI 0.91-0.99, p=0.014). Moreover, women with GDM had a lower uncontrolled eating scale compared to women without GDM (OR 0.118, 95% CI 0.02-0.73, P=0.022).

Conclusions

During pregnancy, women with GDM improved their diet quality, and had a lower uncontrolled eating scale, when compared to women without GDM.

Key Words

Gestational diabetes, lifestyle intervention, risk factors, Cape Town

4.1 INTRODUCTION

Gestational diabetes mellitus (GDM) is defined as "diabetes diagnosed in the second and third trimester of pregnancy that was not clearly overt diabetes before gestation" (American Diabetes Association, 2018). Contextually, the prevalence of GDM has been on the rise (16.9%) over the last few years globally, largely due to obesity (Buckley et al., 2012) and older age in pregnancy (Li et al., 2020b). Although, the prevalence of GDM largely varies by ethnicity and type of diagnosis (Zhu and Zhang, 2016) majority of the cases are reported in the low-and middle-income countries due to the limited access to maternal care (Zhu and Zhang, 2016). According to a systematic review conducted in Sub-Saharan Africa, the prevalence of GDM was reported as 14% when women with at least one risk factor were studied (Adam and Rheeder, 2017a). Moreover, a higher prevalence of 25.8% was reported in South Africa when universal screening and the International Association of Diabetes in Pregnancy Study Groups (IADPSG) criteria were used (Adam and Rheeder, 2017a)

When poorly managed, women with GDM and their offspring can have significant health problems. The mothers can have an increased risk of pre-eclampsia, cardiovascular diseases, and maternal morbidity while the offspring can be at an increased risk of stillbirth, congenital malformation, and prenatal death (Depla et al., 2021, Li et al., 2020c, Wahabi et al., 2014). Although glucose homeostasis is restored to non-pregnancy level after delivery, women with GDM are seven-fold more likely to develop T2DM compared with women without GDM during pregnancy (Bellamy et al., 2009). Therefore, the management and treatment of GDM are important in reducing the negative health impacts on both the mother and the child (Carolan-Olah, 2016).

Lifestyle interventions such as a healthy diet and physical activity are the recommended treatment for GDM management (Carolan-Olah, 2016, Halse et al., 2014, Anjana et al., 2019). A diet should contain a sufficient amount of micronutrients and macronutrients to support foetal growth, but limit postprandial glucose to support appropriate weight gain during pregnancy (Rasmussen et al., 2020). Notably, the type, amount, and distribution of carbohydrates must be taken into account (Rasmussen et al., 2020). Diets such as the Mediterranean diet, a diet high in fruit and vegetables, low-fat diet have been reported to reduce GDM and improve maternal outcomes (Xiao et al., 2022, Nadeem et al., 2022, Rasmussen et al., 2020). These dietary interventions are aimed at maintaining normal blood glucose levels (Zhang et al., 2021a). A Cochrane review study reported that the provision of a combination of diet and exercise interventions is effective in decreasing the incidence of T2DM in women with GDM (Brown et al., 2017). In South Africa, women diagnosed with GDM at primary care level hospitals are referred to tertiary hospitals for GDM management involving diet and lifestyle recommendations. They are educated on ways to minimize weight gain if the patient has a BMI above 27kg/m^2, regular moderate physical activity; at least 30 minutes daily throughout pregnancy, intake of regular small to moderate portions of low glycaemic index carbohydrates, cessation of smoking, and alcohol abstinence (Webb, 2018). Further, carbohydrates should be complex, low-glycemic index, and be high in fibre and should account for about 40% of the diet, fat should account for 40% (monounsaturated fats are preferred to saturated fats), and protein, 20% of the diet (Webb, 2018). Besides the current individual and group education on diet and lifestyle changes are given to women with GDM in Cape Town (Muhwava et al., 2018), healthcare practitioners need to focus more on counselling and education of GDM women (Muhwava et al., 2019).

Although dietary and lifestyle interventions have been found to reduce the risk of GDM and T2DM, we are uncertain whether the current exposure lifestyle advice received from the public health care facilities have an impact on the pregnant women's dietary intake and physical activity practices. Our study aimed to investigate whether women with GDM made changes to their dietary intake and physical activity compared to controls. Further to consider the effect of food security and eating behaviours on dietary intake. We compared lifestyle factors such as diet and physical activity between women with GDM and those without.

4.2 METHODS

4.2.1 Study design and target population

A case-control study design was used to assess the difference in lifestyles between women with GDM and women without. The study was conducted in Cape Town, South Africa between the years 2011 and 2017. This is the first case-control study evaluating the difference between the two groups in South Africa.

South Africa has a population of 58.5 million (World Bank, 2019) and a life expectancy of 64 years for both males and females. The prevalence of GDM in South Africa is estimated at 25.8% (Dias et al., 2019).

The sample size included 167 cases and 199 controls. Cases were pregnant women aged above 18 years with GDM attending Groote Schuur Hospital-GSH in South Africa, a tertiary hospital for high-risk pregnancies. Using the Western Cape diagnostic criteria, pregnant women were screened for gestational diabetes between the 24th and 28th weeks of gestation with a fasting blood glucose criterion of ≥5.6mmol/l and/or≥7.8 mmol/l two hours 75g post glucose load. Cases were recruited at the GSH waiting room during their routine antenatal visits or in the wards, in consultation with nurses.

Controls were pregnant women aged above 18 years attending antenatal clinics at the Community Health Centre (CHC), who had not previously been diagnosed with GDM. The exclusion criteria were a history of gestational diabetes/ diabetes and multiple pregnancies. After a case enrolment, an eligible control with similar ethnicity and gestational age was recruited until the control was matched with a case to ensure accuracy in data interpretation and to minimise confounding factors. Controls were also recruited in the waiting room during their routine antenatal visits at the CHC clinic.

Trained dieticians and final-year dietetics students administered the research questionnaire. Before conducting data collection, the research assistants were trained in how to interview the participants and use the questionnaire. Cases and controls were recruited as they presented at the health facility. Field workers explained the study to the participants, allowed them to ask questions, and recruited them voluntarily.

Data sources and measurement

4.2.1.1 Questionnaires

Interview-administered questionnaires were used for data collection. The questionnaires were divided into various sections including a socio-demographic, family history of DM, gravida, gestational age, BMI, MUAC, physical activity, substance use, eating behaviour; uncontrolled eating scale and emotional eating scale, cravings, eating pattern, dietary intake, and household food security. Each questionnaire was completed in 30 minutes to 40 minutes.

4.2.1.2 Physical Activity Assessment

Past physical activity (before the current pregnancy) was assessed. Participants were asked to recall how much time they spent per week on physical activities such as walking, planned physical activity, household activity, and sedentary activities. They were also asked whether their level of mentioned activities was the same in their current pregnancy. The total number of minutes per week for each activity was calculated by multiplying the frequency of each exercise by the number of minutes per week.

4.2.1.3 Household Food Security

The Community Childhood Hunger Identification Project (CCHIP) index was used to measure household food insecurity. The CCHIP index is composed of eight questions that assess food insecurity at the household level, the adult individual, and child hunger. It also investigates food shortages, perceived food insufficiency, or changes in food intake resulting from resource constraints. Moreover, for each aspect of hunger, another two questions that explore the extent of food insecurity over 30 days are added (Walsh and Van Rooyen, 2015). Only four questions were included in our study. The four questions that were not included relate to child hunger and did not apply to the whole sample as many participants could be in their first pregnancy. The first three questions that were included focused on household food security while the last question focused on individual food security. To calculate household food security, participants were classified to be household food insecure if they answered yes to at least 3 of the 4 questions, at risk of food insecurity if they answered yes to 1 or 2 questions, and food secure if they answered no to all the questions focusing on household food security. The same method was applied in calculating overall food insecurity.

4.2.1.4 Three-Factor Eating Questionnaire (TFEQ-R18)

This section included questions on eating behaviour. The TFEQ-R18 was used to describe eating behaviour. This is a shortened version of the original TFEQ which consisted of 51 items (Karlsson et al., 2000). The questionnaire measures three different aspects of eating behaviour and is divided into cognitive restraint scale consisting of 6 questions, an uncontrolled eating scale- of 9 questions, and an emotional eating scale, with 3 questions. The 18 items on the TFEQ-R18 have a 4-point response scale (definitely true/mostly true/mostly false/definitely false) which is given a score between 1 and 4 and summed into the three subscales (cognitive restraint scale, uncontrolled eating scale, and emotional eating scale). The raw scale scores are transformed to a 0-100 scale by multiplying by 100, and higher values indicate greater cognitive restraint, and uncontrolled or emotional eating (Karlsson et al., 2000).

4.2.1.5 Dietary intake during the past month

A dietary assessment was done to determine the frequency of food and drink consumption in the last month, during the current pregnancy. A non-quantified food frequency questionnaire (FFQ) consisting of 49 food items was developed for this study. The frequency of food/drink intake of each food item was recorded per day, week or month. The frequency of weekly intake of all consumed foods/drinks was then calculated by dividing foods consumed in a month by 4 and multiplying foods consumed per day by 7. The food items were further grouped into 10 groups (Table 4.1) by adding up the values obtained from the weekly intake of each food/drink in a food group. The food groups were adapted from a study by Seme, which assessed the healthfulness of food choices among educators in the Western Cape (Seme, 2013).

Table 4.1 Food groups derived from the food frequency questionnaire

Food groups	**Food Items included**
High-fat foods	Red meat, organ meat, fried fish, fried chicken, chicken with skin, pies, sausage rolls, samosas, vetkoek, Gatsby, sausages: viennas, Russians, Boerewors, polony, cold meats, salami, tinned meat (bully beef), eggs with fat, cheese, cottage cheeses full cream, full cream milk, normal yoghurt, potato fried/chips (with fat)/roti, take away/restaurant/street vendors
Low-fat foods	Fish other (tinned/fresh/smoked), eggs without fat, low-fat cottage cheese, fat-free cottage cheese, low-fat milk, fat-free milk, fat-free plain yoghurt, tub margarine, lite mayonnaise
Fats	Butter, hard margarine, lite margarine, sunflower oil, olive/canola oil, normal mayonnaise, lite mayonnaise, peanut butter
Fruits and vegetables	Fruit fresh, vegetables, potato (including in stew)
High fibre foods	Brown bread, whole wheat bread, high fibre cereals, legumes: beans, lentils, soya etc,
Refined Carbohydrates	White bread, oats or maltabella porridge, maize porridge, low fibre cereals, rice, pasta, samp, Sugar added to tea and coffee, sugar added in cooking, jam/syrup/honey, savoury biscuits: salty cracks, cream crackers, rusks
Added sugar	Sugar added to tea and coffee, sugar added in cooking
Energy-dense snacks	Sweets, chocolate, ice-cream, pudding, custard, cake/tart/muffin/scone/cookies, sweet biscuits, crisps
Sugar-sweetened beverages (SSB)	Fruit juice, cold normal carbonated drinks, cold normal syrup mix
Alcohol	Wine, beer/cider/cooler, spirits (vodka, brandy, whiskey)

4.2.1 Sample size and recruitment

Using Epi Info and for a power of 80%, alpha error of 5%, and using a GDM prevalence of 25.8% in South Africa (Dias et al., 2019a) and odds ratio of 1.5 the minimum sample size was

167 cases and 199 control. Post hoc power analysis showed that the study had sufficient power to detect significant differences in diet, substance use, physical activity, and TFEQ-R18

4.2.2 Data analysis

STATISTICA version 12 (Statsoft © 2012) was used to clean the data and for all statistical analyses. Continuous data were tested for normality using histograms. For descriptive purposes, percentages were calculated for categorical variables, while means and standard deviations were calculated for normal continuous variables and medians and interquartile ranges for non-normal continuous variables. To compare variables between the cases with controls, Pearson's Chi-Square test was used for categorical variables, and the Independent samples t-test was used for continuous variables. A of $p<0.05$ was considered statistically significant. We adjusted for age, mid-upper arm circumference (as a measure of adiposity), gestational age and the number of pregnancies, using multiple variable logistic regression, with GDM (yes/ no) as the outcome, and reported odds ratios (OR) and their 95% confidence intervals (95%CI).

4.2.3 Ethical approval

Ethical approval for this study was obtained from the University of Cape Town, Faculty of Health Sciences, Human Research Ethics Committee (ref no: 111/2011 and 113/2011). Institutional permission was obtained from the South African Department of Health, the superintendent of GSH, and the facility manager at the CHC. Written informed consent was obtained from each participant prior to the interview.

4.3 RESULTS

4.3.1 Socio-demographic characteristics

The total number of participants in this study was 366, consisting of 167 (45.6%) cases and 199 (54.4%) controls. In the analysis, cases and controls were similar concerning ethnicity, smoking history, gestational age, and food security. Comparing cases to controls, the median age differed significantly between the two groups (32.5 vs. 25; $p<0.001$). The proportion of current alcohol consumption for cases was (0%), which was significantly lower than that of controls (2.5%) ($p=0.017$). The proportion of participants with a family history of DM was significantly higher among cases (50.6% vs 20.7; p<0.001) than among controls. Cases had a significantly higher median BMI (35.9 vs 29.3; p<0.001) and MUAC (34.5 vs. 29.3; p<0.001) compared to their counterparts. Similarly, median gravida was higher among women with GDM (3.0 vs, 2.0, p<0.001). (Table 4.2).

Table 4.2 Comparison of socio-demographic characteristics between Cases and Controls

Socio-demographic	**Cases, n=167**	**Controls, n=199**	p-value
Age, median (IQR)	32.5 (28.0-37.0)	25 (22.0-31.0)	<0.001[c]
Ethnicity, n (%)	**N (%)**	**N (%)**	0.449[b]
Black	81 (47.9)	98 (49.3)	
Mixed[a]	82 (48.5)	98 (49.3)	
Asian	6 (3.6)	3 (1.5)	
Ever drunk alcohol, yes n (%)	50 (29.9)	74 (37.2)	0.144[b]
Current alcohol, n (%)	0 (0.0)	5 (2.5)	0.017[b]
Ever smoked, yes n (%)	57 (34.1)	71 (35.7)	0.575[b]
Currently smoking, n (%)	23 (13.8)	43 (21.6)	0.146[b]
Family history of DM, n (%)	84 (50.6)	41 (20.7)	<0.001[b]
Gravida, Median (IQR)	3.0 (2.0-4.0)	2.0 (1.0-3.0)	<0.001[c]
Gestational age, median (IQR)	33.0 (29.0-36.0)	32.0 (28.0-36.0)	0.178[c]
BMI, median (IQR)	35.9 (31.2-41.2)	29.3 (26.0-33.6)	<0.001[c]
MUAC Median (IQR)	34.5 (31.0-37.3)	29.3 (25.7-31.5)	<0.001[c]
Household food security n (%)			0.068[b]
Food secure	93 (55.7)	84 (42.2)	
At risk of food insecurity	47 (28.1)	79 (39.7)	
Food insecure	27 (16.2)	36 (18.1)	
Overall food security n (%)			0.135[b]
Food secure	92 (55.1)	84 (42.2)	
At risk of food insecurity	36 (21.6)	57 (28.6)	
Food insecure	39 (23.4)	58 (29.2)	

[a] Mixed race-ancestry are a population in Cape Town, South Africa with mixed genetics from Khoisan, African Bantu, Northern European and South Asia. [b] Chi-squared test. [c] Wilcoxon rank-sum test (non-normal data).

4.3.2 Physical activity

There were significant differences between women with GDM and women without GDM in the level of walking and household activity in the past month, in the univariate analysis (Table 4.2). A higher proportion of GDM women indicated that they have stopped walking during pregnancy (14.9% vs. 2.5%, p<0.001) compared to non-GDM women, while more non-GDM women indicated that their walking level during pregnancy was either the same (53% vs. 47.3%, p<0.001) or more (6.6% vs. 4.1%, p<0.001) than before pregnancy, before adjusting for confounding factors. A similar pattern emerges for household activity. There was no significant difference between women with GDM and women without GDM in all physical activity domains after adjusting in adjusted analyses (Table 4.3).

Table 4.3 Comparison *of physical activity between cases and controls*

Physical activity	**Cases, n=167**	**Controls, n=199**	p-value	Adjusted OR (95%CI)	p-value from adjusted analysis
Walking level in the past month, n (%)			<0.001[b]	1.07 (0.76-1.50)	0.715
Same as before pregnancy	70 (47.3)	105 (53.0)			
Less than before pregnancy	50 (33.8)	75 (37.9)			
Stopped during pregnancy	22 (14.9)	5 (2.5)			
More than before pregnancy	6 (4.1)	13 (6.6)			
Planned physical activity level in the past month, n (%)			0.326[b]	1.30 (0.91-1.87)	0.151
Same as before pregnancy	128 (76.7)	159 (79.9)			
Less than before pregnancy	11 (6.6)	6 (3.0)			
Stopped during pregnancy	28 (16.8)	33 (16.6)			
More than before pregnancy	0 (0.0)	1 (0.5)			
Household activity level in the past month, n (%)			0.026[b]	1.16 (0.82-1.65)	0.393
Same as before pregnancy	74 (47.7)	104 (53.9)			
Less than before pregnancy	65 (41.9)	71 (36.8)			
Stopped during pregnancy	9 (5.8)	2 (1.0)			
More than before pregnancy	7 (4.5)	16 (8.3)			
Sedentary activity level in past month n (%)			0.468[b]	0.99 (0.81-1.21)	0.928
Same as before pregnancy	77 (49.4)	94 (48.0)			
Less than before pregnancy	24 (15.4)	24 (12.2)			
Stopped during pregnancy	1 (0.6)	0 (0.00)			
More than before pregnancy	54 (34.6)	78 (39.8)			
Walking (Minutes per week), Mean, SD	270.4 (321.1)	261.2 (386.3)	0.803[c]	1.00 (1.00-1.00)	0.349
Planned physical activity (minutes per week), mean, SD	50.1 (132.5)	48.6 (156.2)	0.919[c]	1.00 (1.00-1.00)	0.590
Household activities (Minutes per week) mean, SD	841.3 (727.3)	840.5 (749.8)	0.992[c]	1.00 (1.00-1.00)	0.486
Sedentary activities (Minutes per week), mean, SD	1462.7 (1150.3)	1342.4 (1146.4)	0.319[c]	1.00 (1.00-1.00)	0.656

[b] Chi-squared test. [c] Wilcoxon rank-sum test (non-normal data).

*Odds ratios adjusted for age, mid-upper arm circumference, gestational age and number of pregnancies

4.3.3 Dietary intake during the past month

Women with GDM reported consuming a higher median of low-fat foods (7.0 vs. 4.0, $p<0.001$) and higher median of fibre carbohydrates (8.0 vs. 6.0, $p=0.002$) when compared to women without GDM. Women with GDM consumed a lower median of high-fat foods (17 vs. 26, $p<0.001$), refined carbohydrates (11.7 vs. 14, $p=0.016$), added sugar (7.0 vs. 7.0, $p<0.001$), sugar-sweetened beverages (4.0 vs. 7.0, $p=0.006$) and energy-dense snack (3.0 vs. 9.0, $p<0.001$), compared to women without GDM. However, in adjusted analyses, consumption of low fat food (OR 1.06, 95% CI 1.02-1.10, $p=0.003$), high fibre carbohydrates (OR 1.07, 95% CI 1.01-1.12, $p=0.011$), added sugar (OR 0.94, 95% CI 0.90-0.98, $p=0.001$) and energy dense snacks (OR 0.91, 95% CI 0.91-0.99, $p=0.014$) remained significant while there were no significant associations in high fat foods, refined carbohydrates and sugar sweetened beverages (Table 4.4).

Table 4.4 Comparison *of dietary intake during the past month between cases and controls*

Indicator food groups	Cases, n=167		Controls, n=199		p-value	Adjusted OR(95%CI)	Adjusted p-value
	Median (IQR)[d]	**Mean [33]**	**Median (IQR)[d]**	**Mean [33]**			
High fat foods	17.0 (11.0-25.0)	19.7 (10.9)	26.0 (19.0-32.3)	25.9 (10.3)	<0.001[c]	0.98 (0.95-1.00)	0.102
Low fat foods	7.0 (2.3-12.3)	8.9 (9.5)	4.0 (1.0-9.0)	5.8 (6.2)	<0.001[c]	1.06 (1.02-1.10)	0.003
Fats	15.0 (9.0-20.0)	15.1 (8.2)	15.5 (12.0-21.0)	16.2 (10.1)	0.157[c]	1.01 (0.97-1.05)	0.538
Fruits and vegetables	15.0 (10.0-24.0)	17.8 (10.1)	16.0 (11.0-21.0)	17.5 (5.3)	0.799[c]	1.01 (0.98-1.04)	0.457
High fibre carbohydrates	8.0 (3.0-12.0)	8.5 (6.3)	6.0 (2.0-10.0)	6.5 (6.1)	0.002[c]	1.07 (1.01-1.12)	0.011
Refined carbohydrates	11.7 (7.0-15.0)	11.7 (6.8)	14.0 (9.0-17.0)	13.4 (11.2)	0.016[c]	1.00 (0.96-1.05)	0.872
Added sugar	7.0 (0.0-7.0)	6.0 (6.9)	7.0 (7.0-10.0)	10.2 (6.3)	<0.001[c]	0.94 (0.90-0.98)	0.001
Sugar sweetened beverages	4.0 (0.0-7.0)	5.5 (7.5)	7.0 (3.0-10.0)	7.5 (11.2)	0.006[c]	0.99 (0.95-1.02)	0.442
Alcohol	0.0 (0.0-0.0)	0.0 (0.0)	0.0 (0.0-0.0)	0.0 (0.2)	0.170[c]	-	-
Energy dense snack	3.0 (0.0-8.0)	5.6 (7.1)	9.0 (5.0-15.0)	10.4 (9.0)	<0.001[c]	0.95 (0.91-0.99)	0.014

[c] Wilcoxon rank-sum test (non-normal data). [d] values represent the median frequency of intake of indicator food groups per week (times per week)
*Odds ratios adjusted for age, mid-upper arm circumference, gestational age and number of pregnancies

4.3.4 Food cravings, Eating patterns and TFEQ-R18

Women with GDM had lower uncontrolled eating when compared to women without GDM (OR 0.12, 95% CI 9.02-0.73, P=0.022). There were no differences between women with GDM and women without GDM in food cravings and eating patterns, cognitive restraint and emotional eating scales after adjusted analyses (Table 4.5).

Table 4.5 Comparison *of Cravings, Eating Patterns, and TFEQ-R18 between Cases and Controls*

	Cases, n=167	**Controls, n=199**	p-value	**Adjusted OR (95%CI)**	**Adjusted p-value**
Participant experience craving in the current pregnancy, n (%) Yes	90 (53.89)	111 (55.78)	0.718[b]	0.91 (0.51-1.57)	0.728
Foods that they craved, n (%) Yes					
Chocolate and sweets	37 (41.1)	44 (39.6)	0.833[b]	1.16 (0.53-2.55)	0.703
Take outs	29 (32.2)	40 (36.0)	0.571[b]	1.06 (0.46-2.42)	0.895
Fruits and vegetables	34 (37.8)	39 (35.1)	0.698[b]	0.97 (0.44-2.13)	0.936
Sugar-sweetened beverages	6 (6.7)	15 (13.	0.115[b]	1.63 (0.41-6.43)	0.487
Meat	6 (6.7)	14 (12.6)	0.161[b]	1.81 (0.41-8.12)	0.431
Eating pattern, number of days per week a participant eats					
Before Breakfast, Median (IQR)	0.0 (0.0-0.0)	0.0 (0.0-0.0)	0.056[c]	0.93 (0.82-1.05)	0.245
Mean (SD)	0.8 (2.0)	1.2 (2.5)			
Breakfast, Median (IQR)	7.0 (7.0-7.0)	7.0 (6.0-7.0)	0.093[c]	1.11 (0.97-1.28)	0.130
Mean (SD)	6.2 (1.7)	5.9 (1.5)			
Mid-morning snack, median (IQR)	4.0 (1.0-7.0)	3.0 (0.0-7.0)	0.054[c]	1.08 (0.99-1.18)	0.90
Mean (SD)	4.0 (2.9)	3.4 (3.1)			
Lunch, median (IQR)	7.0 (7.0-7.0)	7.0 (7.0-7.0)	0.993[c]	1.02 (0.86-1.22)	0.779
Mean (SD)	6.3 (1.5)	6.3 (1.6)			
Mid-afternoon snack, median (IQR)	3.0 (0.0-7.0)	3.0 (0.0-7.0)	0.205[c]	0.97 (0.88-1.06)	0.444
Mean (SD)	3.3 (3.0)	3.7 (3.1)			
Supper, median (IQR)	7.0 (7.0-7.0)	7.0 (7.0-7.0)	0.388[c]	0.89 (0.70-1.10)	0.256
Mean (SD)	6.6 (1.3)	6.7 (1.1)			
After supper, median (IQR)	0.0 (0.0-0.0)	0.0 (0.0-0.4)	0.729[c]	1.08 (0.98-1.19)	0.100
Mean (SD)	2.5 (3.0)	2.4 (2.9)			
Wake up at night to eat, median (IQR)	0.0 (0.0-0.0)	0.0 (0.0-2.0)	0.114[c]	1.04 (0.92-1.18)	0.524
Mean (SD)	1.0 [34]	1.3 (2.4)			
TFEQ-R18[d]					
Cognitive Restraint Scale, median (IQR)	37.5 (29.2-45.8)	35.5 (25.0-41.7)	0.212[c]	0.46 (0.35-6.09)	0.556
Mean (SD)	15 (2.7)	15.4 (2.5)			
Uncontrolled Eating Scale, median (IQR)	22.2 (13.9-33.3)	30.6 (19.4-41.7)	<0.001[c]	0.12 (0.02-0.73)	0.022
Mean (SD)	24.4 (3.9)	23.0 (4.6)			
Emotional Eating Scale, median (IQR)	16.7 (0.0-33.3)	16.7 (0.0-25.0)	0.139[c]	1.37 (0.37-5.10)	0.638
Mean (SD)	9.4 (2.7)	9.8 (2.6)			

[b] Chi-squared test. [c] Wilcoxon rank-sum test (non-normal data). [d] **TFEQ-r18** – Three-factor eating questionnaire- R18
*Odds ratios adjusted for age, mid-upper arm circumference, gestational age and number of pregnancies

4.4 DISCUSSION

In our present study, women with GDM had higher BMI and a family history of diabetes which are known risk factors for GDM. We observed that women with GDM were more likely to eat low-fat foods and high-fibre foods while they were less likely to eat added sugars and energy-dense snacks. Additionally, women with GDM had lower uncontrolled eating scale scores, when compared to women without GDM. We did not observe a significant difference in physical activity between women with GDM and those without GDM after adjusting for age, MUAC, gestational age and gravida. Moreover, food cravings and eating patterns were equally not statistically significant after adjusting for confounding factors. Many studies have reported the benefits of diet and physical activity in preventing and delaying the onset of T2DM among women with GDM (Anjana et al., 2019, Asemi et al., 2014, Teede et al., 2022). However, to the best of our knowledge, this is the first study that has investigated the difference in lifestyle changes in pregnancy between women with GDM and those without GDM.

Our dietary intake results indicate that women with GDM seem to follow a healthier diet than those without GDM. This could be attributed to the interventions received at the public health care facilities that involves dietary intake education by a dietitian during at least one session. Our finding is consistent with the St Carlos study conducted in Spain, which reported higher adherence to the Mediterranean diet among diabetic women at late gestational age (García de la Torre et al., 2019). Women with GDM ate fewer fat foods, reduced their intake of high-fat foods, and increased their intake of high-fibre carbohydrates while reducing consumption of refined carbohydrates when compared to women without GDM. Dietary interventions have been shown to reduce the risk of GDM among pregnant women (Anjana et al., 2019, Carolan-Olah, 2016), while a higher intake of animal dietary fat before and during pregnancy increases the risk of GDM (Bowers et al., 2012, Shin et al., 2015). A study conducted in Finland observed a decrease in fat intake among women with GDM risk who received individual counseling on diet (Korpi-Hyövälti et al., 2012). Moreover, SEMDSA recommends the use of monounsaturated fats when compared to saturated fats (Webb, 2018). In our study, women with GDM reduced their intake of refined carbohydrates (high glycaemic index foods) and increased their intake of high-fibre carbohydrates (low glycaemic index foods). A diet high in fibre reduces adiposity, due to low caloric intake resulting from reduced appetite and slowed digestion, therefore, reducing insulin resistance (Liese et al., 2005). According to Zhang et al., a daily 10g increase in total fibre intake reduced GDM risk by 26% (Zhang et al., 2006). Notably, Looman et al. (2018), in a study conducted in Australia stated that the source of dietary fibre should be taken into account since fibre from cereals increased GDM risk in their study, while fibre from fruits and fruit juice reduced GDM risk (Looman et al., 2018).

We also observed a decrease in the consumption of added sugar and energy-dense snacks among women with GDM when compared to women without GDM. Dietary patterns with high-added sugars in beverages and food have been associated with an increase in GDM risk (Shin et al., 2015, Gamba et al., 2019). A study conducted in the US (Nurses' Health Study II) reported an elevated GDM risk with high pre-pregnancy consumption of sugar-sweetened cola (Chen et al., 2009). This is because foods high in sugars may lead to obesity, hence resulting in reduced insulin sensitivity. Furthermore, Sedaghat et al. (2017), found an increase in GDM risk with Western dietary patterns characterized by energy-dense snacks in a study conducted in Iran (Sedaghat et al., 2017). Higher scores on the uncontrolled eating scale were linked with higher gestational weight gain in pregnancy in the study of Tang et al. (2020), but the relationship was no longer significant when adjusted for socio-demographic characteristics and BMI (Tang et al., 2020). In our study, a lower number of women with GDM had uncontrolled eating when compared to women without GDM. This means that women with GDM had better control of their eating, possibly as a result of diet interventions by the dietitian.

Physical activity is important before and during pregnancy as it reduces insulin resistance in GDM (Embaby et al., 2016, Yong et al., 2020a). According to some studies, the recommended physical activity duration is 30-45 minutes (Embaby et al., 2016, Colberg et al., 2013) for physical activity during pregnancy, with a meal consumed 1-3 hours before exercising (Embaby et al., 2016). According to Brown et al. (2017) study, exercises such as jogging, low-intensity aerobic exercises, and running are safe during pregnancy (Brown et al., 2017) and are associated with reduced fasting and postprandial blood glucose concentration. Therefore, knowledge of the contraindications of physical activity and counselling on the importance of physical activity in pregnancy is vital for the health of the mother and their offspring (Bianchi et al., 2021). In our study, women with GDM spent more minutes in a week walking, engaging in planned physical activities, and household and sedentary activities before pregnancy when compared to women without GDM, although this was not statistically significant after adjusting for age and MUAC. Nonetheless, the level of walking and household activity during pregnancy was lower among women with GDM when compared to women without GDM. The proportion of pregnant women engaging in physical activity in our study is similar to a previous study conducted in South Africa (Muzigaba et al., 2014). Elsewhere in Italy, a study reported a high proportion of sedentary lifestyles among women with GDM (Bianchi et al., 2021), which is consistent with our study findings. We attribute our findings to illness reported by some women with GDM resulting in them being admitted to a high-risk hospital, which could have influenced their ability to exercise during pregnancy. Moreover, participants were asked to recall their levels of physical activities before pregnancy, which might have resulted in misreporting and recall bias. These results are important for health practitioners to focus more on educating women with GDM on the importance of exercising during pregnancy, to better maternal and infant outcomes.

There was no significant difference in household food security between women with GDM and women without GDM in our study. These findings are corroborated by Janzadeh et al. (2020), in a study conducted in Iran, which did not find a difference in food security and GDM between cases and controls (Janzadeh et al., 2020). Elsewhere, Laraia et al. (2019), reported contrary findings where they observed increased weight gain in pregnancy and GDM with food insecurity (Laraia et al., 2010). The author attributed his findings to the consumption of highly palatable foods due to stress or/and dependence on cheap, calorie-dense foods (Laraia et al., 2010).

Alcohol consumption during pregnancy, especially in the first trimester has adverse foetal outcomes, such as low-birth-weight and preterm births (Nykjaer et al., 2014). In our study, current alcohol consumption was more prevalent among women without GDM. The difference observed in the current alcohol consumption could be attributed to the cessation of consumption, by women with GDM due to lifestyle changes. Although some studies have found an association between smoking and GDM risk (Erem et al., 2015a, Leng et al., 2016), this was not the case in our present study.

The strengths of our study include interviews being conducted in the participant's language of choice, which enabled better understanding and clarity of the questions during the interview. Moreover, field workers were well trained and standardised on data collection tools, procedures, and measurements to ensure the accuracy of the data collected. The limitation of this study was potential recall bias while collecting data on dietary recall in the past month. This is because the participants had to recall and self-report, limiting the accuracy of the data. However, participants were shown cards with images of food, which helped them recall their food intake.

4.5 CONCLUSION

From the study findings, women with GDM improved their diet quality, had lower uncontrolled eating, and reduced their alcohol intake in pregnancy when compared to women without GDM. Moreover, there was no difference in physical activity, food cravings, eating patterns, and smoking between women with GDM and those without GDM. Future studies should investigate the effect of these lifestyle changes on pregnancy outcomes and insulin control among women with GDM in Cape Town, South Africa. There are no studies known to us in Cape Town, South Africa that has investigated lifestyle changes in pregnancy between women with GDM and those without. Moreover, our study contributes to the body of knowledge on the impact of lifestyle intervention on GDM in our population.

Chapter 5: Conclusions and Recommendation

GDM is associated with neonatal complications, birth difficulties, and abnormal pregnancies, which include; maternal T2DM after pregnancy and preeclampsia, stillbirth, macrosomia, foetal cardiac hypertrophy, and diastolic dysfunction (Li et al., 2020a, Depla et al., 2021, Muche et al., 2020). There is an increase in GDM prevalence globally and it has been recently reported to be higher in high-income countries (Wang et al., 2022). In South Africa, prevalence defers depending on the different screening methods used. For instance, research that investigated five hundred and fifty four patients reported a prevalence of 25.8% when the IADPSG criteria were used and 17.0% when the National Institute for Health and Care Excellence (NICE) was used, under the universal screening method. However, when selective risk factor-based screening was used, the prevalence was 15.2% for the IADPSG method and 3.6% when NICE was used (Adam and Rheeder, 2017a). Understanding GDM risk factors helps in creating timely interventions and treatment, hence reducing maternal and foetal adverse effects. We, therefore, conducted a case-control study to investigate GDM risk factors and compared lifestyle changes between women with GDM and those without, living in Cape Town, South Africa.

Our study included three hundred and sixty six pregnant women above 24 weeks gestation, one hundred and seven had GDM in pregnancy while one hundred and ninety nine were without GDM. The participants were (48.6%) black women, (48.9%) with mixed ancestry, and Asian (2.5%). The majority of the participants completed secondary school level education, were employed, and received a social grant. Significantly, women with GDM were married or lived with their partners, when compared to women without GDM. However, this difference was not significant after matching for age.

Women with GDM had a significantly high current weight, BMI, MUAC, and pre-pregnancy weight compared to women without GDM. Furthermore, they thought they were overweight before pregnancy and that they had gained too much weight during the current pregnancy when compared to women without GDM. We established that the optimum cut-off point for predicting GDM was 30.1cm for MUAC, with a sensitivity of 84%, a specificity of 59%, and an AUR of 71% and 32.4kg/m^2 for BMI with a sensitivity of 68%, a specificity of 68% and an AUR of 68%. MUAC is a fast tool to monitor pregnancy nutritional status when compared to BMI (Miele et al., 2021). Recently, a meta-analysis study with 14 datasets reported that general obesity, central obesity, and visceral body fat increase the risk of GDM (Alwash et al., 2021).

According to SEMDSA guidelines, intensive lifestyle interventions which include diet, physical activity, and behavioural therapy should be offered to obese and overweight patients with T2DM as modest weight loss (5-10%) improves glycaemic control and cardiovascular risk (Webb, 2018).

Although the gestational age of women with GDM and those without GDM was similar at recruitment, women with GDM had significantly higher gestational age after matching for age. Moreover, they had a significantly higher number of previous pregnancies, live births, miscarriages, and stillbirths when compared to their counterparts. The above observations are explained by our findings that cases were older compared to controls. Therefore, these factors were no longer significant after matching for age. Furthermore, we observed that women with GDM had a significantly higher previous history of GDM (28.6%), hypertension (29.0%), and preeclampsia (8.3%) in their current pregnancies, a family history of DM (50.6%) and GDM (13.8%) compared to women without GDM. These factors remained significant even after matching for age. There is a need for more research on the relationship between GDM and stillbirth (Lemieux et al., 2022). Although stillbirth was established as a risk factor for GDM in our study, this finding should be interpreted cautiously as we recruited participants from a high-risk level hospital, therefore, a history of stillbirth could have been linked to other medical complications. Moreover, a family history of DM and GDM are well-established risk factors for GDM development, which was also evident in our study outcomes. It is therefore important for pregnant women to be well conversant with their family medical history to take timely precautions and lifestyle changes that will alleviate GDM risk and its consequences. Research has shown that GDM is likely to recur from one pregnancy to another (Morikawa et al., 2021, Egan et al., 2021). According to Morikawa et al. (2021), the recurrence rate of GDM in a study that investigated six hundred and fifteen Japanese women was 47.2%, and the predictor for GDM recurrence was an OGTT score of 2 to 3 positive points in the first pregnancy. Therefore, lifestyle changes such as weight loss for overweight and obese pregnant women after pregnancy is important to reduce the chances of GDM recurrence in subsequent pregnancies.

GDM modifiable risk factors are those that can be changed through lifestyle modifications such as a healthy diet, physical activity, and quitting alcohol consumption and smoking. In South Africa, SEMDSA recommends that patients diagnosed with diabetes should be offered an education that mainly focuses on medical nutritional therapy (MNT), physical activity, and behavioural changes, which helps with both diabetes prevention and management. Having recruited women with GDM from a high-risk hospital, they were on treatment which included

MNT and had been educated on physical activity and behavioural changes. We, therefore, noted some differences between women with GDM and those without GDM as a result of the intervention.

In our study, women with GDM consumed a higher intake of low-fat foods and high-fibre carbohydrates while they reduced their intake of high-fat foods, refined carbohydrates, added sugar, sugar-sweetened beverages, and energy-dense snacks when compared to women without GDM. Our study indicates that women with GDM followed SEMDA guidelines on nutrition interventions for GDM treatment. The objective of MNT is for patients to achieve and maintain blood pressure, lipid, and body weight goals and prevent diabetes complications (Webb, 2018). Therefore, medical practitioners including dietitians should offer individualized and timely education to women with GDM (Hui et al., 2014). Besides, we did not observe a difference in food cravings and eating patterns between women with GDM and those without GDM. It was interesting to note that women with GDM had a lower uncontrolled eating scale when compared to women without GDM. This means that they consciously made better food choices. However, there was no difference in cognitive restraint score and emotional eating scales between the two groups.

Our study found a significant difference between women with GDM and those without in the level of walking and household activity in the past month. A bigger proportion of women with GDM (14.9%) indicated that they had stopped walking during their pregnancy compared to controls (2.5%). This could be explained by the fact that women with GDM were unwell and some were admitted to hospital wards. However, medical practitioners should encourage women admitted to hospitals to engage in some form of physical activity such as walking around the premises. Importantly, considerations should be made in case there are other complications such as orthopaedic injuries and heart conditions. We did not find a significant difference in planned physical activity, sedentary activities, minutes per week engaging in planned physical activity, walking, household, and sedentary activities between the two groups.

Alcohol consumption was lower (0%) among women with GDM compared to women without GDM (2.5%). Although there is inadequate research linking alcohol consumption to GDM risk, pregnant women need to quit alcohol during pregnancy because of other complications related to alcohol consumption in pregnancy (Hu et al., 2021). Smoking in current pregnancy was lower in women with GDM (13.8%) compared to women with GDM (21.6%). Unfortunately, there was a percentage of women smoking during pregnancy despite the negative effects of smoking. Prenatal smoking has been linked with an increase in GDM risk (Bar-Zeev et al., 2020). Therefore, women in their reproductive age should be educated about the effects of smoking to promote cessation of smoking among pregnant women. Additionally, there is a need for more studies on smoking and GDM risk in the South African population.

Finally, 53.2% of cases were on oral hyperglycaemic treatment, 13.5 % on insulin, 13.1% on both insulin and oral tablets, and 19.8% did not receive any pharmacological treatment. Women with GDM generally prefer oral tablets compared to insulin injections due to the stigma that comes with insulin injections.

Recommendations

From the findings of our study, we recommend the following to help reduce the increasing GDM prevalence among women in Cape Town, South Africa;

- ✓ Women in their reproductive age should be educated about good nutrition for a healthy pregnancy.
- ✓ Counselling and education given by dietitians and medical practitioners should equally focus on other factors such as physical activity, alcohol and smoking, which affect GDM development.
- ✓ More sessions with dietitians and health care professional would potentially be required to optimize behaviour change and improve diet and physical activity further.
- ✓ Women should do medical check-ups often to treat existing conditions such as pre-pregnancy overweight and obesity which are some of the risk factors of GDM.
- ✓ Women with MUAC greater than 30.1cm and BMI greater than 32.4kg/m^2 should consider lifestyle modifications to reduce the risk of GDM
- ✓ A BMI of 32.4kg/m^2 should be used as a cut-off point for predicting GDM for South African women.
    - More research needs to be conducted in other South African regions to ascertain this finding.
- ✓ MUAC of 30.1cm could be used as a cut-off point for predicting GDM for South African women.
    - More research is needed in South Africa to confirm this finding.
- ✓ Overweight and obese women with GDM should be encouraged to adopt healthy living after pregnancy such as weight loss to avoid the recurrence of GDM in their subsequent pregnancy.

- ✓ Women should seek to understand their family medical history to take early precautions in case of a family history of GDM and DM.
- ✓ More research should be conducted in Africa on risk factors for GDM
- ✓ More research on the impact of GDM interventions should be conducted in the African and South African contexts.
- ✓ More research on the relationship between stillbirth and GDM needs to be conducted.

Limitations

- The interviews took about 30 minutes each to complete and it might have been tedious for the participants, however, field workers ensured participants could take a break in between the interview as per need.
- Participants could have under-reported their dietary intake of unhealthy foods, alcohol consumption during pregnancy, and smoking to impress the field workers.
- Some participants did not have data on weight before pregnancy in their clinic cards, hence they had to recall their pre-pregnancy weight. However, we also used MUAC which is a fast method of measuring nutritional status during pregnancy.
- The use of different field workers could have created inconsistency in data collection. However, all field workers were trained in standardized data collection.
- Some patients did not agree to participate in the study. However, we managed to collect enough data as per our sample size requirement.
- There were some situations where participants could not communicate in English, we however ensured participants were interviewed in a language they understand best. The questionaire was first translated to Afrikaans and isiXhosa and back translated to English while conducting the pilot study, hence reducing translation bias.
- We did not collect data on the exact diet and physical activity interventions that the participants received. However, in South Africa, SEMDSA recommendations enable standard treatment measures across South African hospitals, meaning the participants attending Groote Schuur hospital had received lifestyle interventions for GDM.

Final conclusion

Our study identified increasing high MUAC, family history of DM, and stillbirth to be the risk factors for GDM development among women living in Cape Town. Moreover, cut-off points for predicting MUAC and BMI among women in Cape Town were also established. These cut-off points could be useful in selective GDM screening. Furthermore, while comparing lifestyle changes in pregnancy between women with GDM and women without GDM, women with GDM showed an improvement in their diet, alcohol intake, smoking, and uncontrolled eating scale. Nutrition and lifestyle interventions are important in GDM prevention and treatment and from what we observed, women with GDM are keen to follow the education given to them to have a healthier pregnancy. Our study contributes to the existing body of knowledge on GDM risk factors in South Africa and further highlights new observations on the comparison of lifestyle changes between women with GDM and women without GDM.

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Appendix 1: Further Statistics for Article 2

Table Append1.1 Medical and Pregnancy History

Medical, pregnancy history	**Cases,**		**Controls,**		**P-value**
	N	**Median(IQR)**	**N**	**Median(IQR)**	
Previous birth weights, median (IQR)					
First pregnancy	103	3.17(0.80)	93	3.2(2.6-3.5)	0.01344
Second pregnancy	67	3.29(0.94)	37	3(2.7-3.4)	0.0143
Third pregnancy	25	3.44(0.65)	15	3.2(2.7-3.5)	0.1231
Fourth pregnancy	3	3.2(2.5-3.6)	3	3.5(2.9-3.6)	0.6579

Table Append1.2 Multivariate analysis (logistic regression) for underlying risk factors for GDM

Variable	Multivariate Analysis		
	AOR	95% CI	P-value
Age	1.17	1.10-1.24	<0.001
BMI	1.12	1.08-1.17	<0.001
Gravida	1.00	0.77-1.28	0.985
Stillbirth	3.92	0.39-39.80	0.248
Family history of DM	3.33	1.90-5.82	<0.001

Appendix 2: Questionnaire

Division of Human Nutrition
University of Cape Town

Gestational Diabetes Study 2016

Hosp sticker or insert details	**DOB**
	Age

Control ☐ GDM☐ **Code: __________**

Fieldworker: ______________________

	Anthropometry:	
1	Current weight	
2	Height	
3	MUAC	
4	Prepregnancy weight	
5	Weight gain during current pregnancy	
	Ethnicity:	
6	What is your ethnicity?	Black ☐ Asian/Indian ☐ Mixed ☐ White ☐ Other: ____________________ ☐
7	Are you a South African citizen? *(If yes, skip to question 10)*	Yes ☐ No ☐
8	If no, which country are you from?	Somalia☐ Zimbabwe ☐ Namibia☐ Botswana☐ Other: _____________________☐

	Relevant biochemistry (most recent from folder):								
9	Date	Blood glucose	HbA1c Level	Blood pressure	Presence of glucosuria	CD4	Cr	PO_4	Na
					Yes ☐ No ☐ Level: _____				
					Yes ☐ No ☐ Level: _____				
					Yes ☐ No ☐ Level: _____				
					Yes ☐ No ☐ Level: _____				

	Medical History			
10	Gestational age at the time of interview (check in file as well)			______________weeks
11	Pregnancy history (including current pregnancy):			No. pregnancies _____ No. miscarriage_____ No. live birth_____ No. stillbirths _____
12	Birth weight (BW), date of birth (DOB) and term/preterm births of previous children *(If first pregnancy, skip to question 16 for cases and question 18 for controls)*	**DOB**	**BW**	**Term/Preterm**
		1	1	Term ☐ Preterm ☐
		2	2	Term ☐ Preterm ☐
		3	3	Term ☐ Preterm ☐
		4	4	Term ☐ Preterm ☐
		5	5	Term ☐ Preterm ☐
13	Did you breastfeed your previous children *(If no, skip to question 15)*			Yes☐ No☐
14	If yes, how long did you breastfeed your:	1st child		
		2nd child		
		3rd child		
		4th child		
		5th child		

15	Have you had GDM with a previous pregnancy?	Yes ☐ No☐
16	During your current pregnancy, were you diagnosed with GDM before you were currently admitted to hospital? *(If no or N/A, skip to question 18)*	Yes ☐ No ☐ N/A ☐
17	If yes, what treatment did you receive?	Oral tablets☐ Insulin☐ Both oral & insulin☐ None☐
18	Do you experience/have any of the following in your current pregnancy?	Hypertension☐ Preeclampsia☐ Asthma☐ HIV☐ Iron deficiency anaemia☐ Heartburn☐ Severe nausea and vomiting☐ Pica☐ Constipation☐ Other, specify________
	Socio-demographic information:	
19	What is your highest level of education?	None ☐ Primary☐ Secondary☐ Grade ____ Tertiary☐ Other ________
20	What is your marital status?	Single/Never married☐ Married☐ Living with partner☐ Divorced☐ Widowed☐
21	What type of house do you live in?	Flat ☐ Brick ☐ Wendy house ☐ Informal ☐ Room in house ☐
22	How many adults older than 18 years are in the household (excluding you)?	
23	How many children/teenagers younger than 18 years are in the household?	

24	Do you have a job? *(If no, skip to question 27)*	Yes ☐ No ☐
25	If yes, is it full time or part time?	Full time ☐ Part time ☐
26	What type of work do you do?	Domestic ☐ Clerical/office ☐ Farm work ☐ Cashier ☐ Heavy loads ☐ Other: ________
27	How many other people in the household are employed/have jobs?	
28	Do you receive a social grant, or other financial support? *(If no, skip to question 30)*	Yes ☐ No ☐

29	If yes, what type of grant?	Pension☐ Child support☐ Disability☐ Care-dependency☐ Foster care ☐ Other: ____________
30	Does anyone else in the household receive a social grant?	Yes ☐ No ☐
31	How many dependents do you have?	
	Household food security	
32	Does your household ever run out of money to buy food?	Yes ☐ No ☐
32.1	In the past 30 days?	Yes ☐ No ☐
32.2	5 or more days in the past 30 days?	Yes ☐ No ☐
33	Do you ever rely on a limited number of foods to feed your children because you are running out of money to buy food for a meal?	Yes ☐ No ☐
33.1	In the past 30 days?	Yes ☐ No ☐
33.2	5 or more days in the past 30 days?	Yes ☐ No ☐
34	Do you ever cut the size of meals or skip meals because there is not enough money for food?	Yes ☐ No ☐
34.1	In the past 30 days?	Yes ☐ No ☐
34.2	5 or more days in the past 30 days?	Yes ☐ No ☐
35	Do you ever eat less than you should because there is not enough money for food?	Yes ☐ No ☐
35.1	In the past 30 days?	Yes ☐ No ☐
35.2	5 or more days in the past 30 days?	Yes ☐ No ☐

	Weight history:	
36	What was your birth weight?	_______kg Less than 2.5kg☐ 2.5-4kg☐ More than 4kg☐ Don't know☐
37	Would you describe your weight during most of your childhood years (primary school / younger than 13 years) as being:	Too thin (underweight) ☐ Just about right (normal weight) ☐ Too chubby/fat (overweight) ☐
38	Would you describe your weight during most of your adolescent years (high school / ages 13 to 18) as being:	Too thin (underweight) ☐ Just about right (normal weight)☐ Too chubby/fat (overweight) ☐

39	When you were between the ages of 18 to 25, would you describe your weight as being:	Too thin (underweight) ☐ Just about right (normal weight)☐ Too chubby/fat (overweight) ☐
40	When you were between the ages of 25 to 30, would you describe your weight as being:	Too thin (underweight) ☐ Just about right (normal weight)☐ Too chubby/fat (overweight) ☐ N/A ☐
41	Before your current pregnancy, would you describe your weight as being:	Too thin (underweight) ☐ Just about right (normal weight)☐ Too chubby/fat (overweight) ☐
42	In your current pregnancy, do you feel that your weight gain up to now was	Too little (not enough)☐ Just right☐ Too much☐
43.1	How much weight did you gain during previous pregnancies *(If first pregnancy, skip to question 45)* First pregnancy	1. Not enough ☐ 2. Normal ☐ 3. Too much ☐ ____________ kg
43.2	Second pregnancy	1. Not enough ☐ 2. Normal ☐ 3. Too much ☐ ____________ kg
43.3	Third pregnancy	1. Not enough ☐ 2. Normal ☐ 3. Too much ☐ ____________ kg
43.4	Fourth pregnancy	1. Not enough ☐ 2. Normal ☐ 3. Too much ☐ ____________ kg
43.5	Fifth pregnancy	1. Not enough ☐ 2. Normal ☐ 3. Too much ☐ ____________ kg

44.1	How much weight did you pregnancy retain after (a 1 year period after each of) your previous pregnancies? First	1. Lost it all ☐ 2. Retained a bit ☐ 3. Retained most of it ☐ ____________ kg
44.2	Second pregnancy	1. Lost it all ☐ 2. Retained a bit ☐ 3. Retained most of it ☐ ____________ kg
44.3	Third pregnancy	1. Lost it all ☐ 2. Retained a bit ☐ 3. Retained most of it ☐ ____________ kg

44.4	Fourth pregnancy	1. Lost it all ☐ 2. Retained a bit ☐ 3. Retained most of it ☐ _____________ kg
44.5	Fifth pregnancy	1. Lost it all ☐ 2. Retained a bit ☐ 3. Retained most of it ☐ _____________ kg

Past physical activity (before current pregnancy):

45 *Think of your physical activity levels before your current pregnancy. On average, how much time do you spend per week on the following activities? (Also indicate whether your level of activity is still*

Type of activity	Times per week:	How long (minutes):	During the past month, would you say that your level of this activity is
Walking (excluding at work) (*Probe: from bus/train station; to and from shops, schools etc.; to*			Same as before pregnancy ☐ Less than before pregnancy ☐ Stopped during pregnancy ☐ More than before pregnancy ☐
Planned physical activity/			
Running			Same as before pregnancy ☐ Less than before pregnancy ☐ Stopped during pregnancy ☐ More than before pregnancy ☐
Sports (specify):			
Cycle			
Gym			
Other (specif):			
Household activities:			
Playing with children			Same as before pregnancy ☐ Less than before pregnancy ☐ Stopped during pregnancy ☐ More than before pregnancy ☐
Housework *(washing dishes, ironing, cleaning surfaces, vacuuming,*			
Gardening			
Leisure activities:			
Watch TV			Same as before pregnancy ☐ Less than before pregnancy ☐ Stopped during pregnancy ☐ More than before pregnancy ☐
Sit/lie reading books/magazines			
Using a computer/ games			

Substance use:

46	Have you ever smoked? *(If no, skip to question 50)*	Yes, currently ☐ No ☐ Yes, but stopped during pregnancy ☐ Yes, but stopped before pregnancy ☐
47	If yes, how many years have you been smoking for?	Specify__________
48	If you do smoke currently, how many cigarettes do you smoke?	Not every day☐ Less than 5 per day☐ 5-9 per day☐ 10-15 per day☐ 16-20 per day☐ More than a pack a day☐
49	Do you usually eat less when you are smoking?	Yes ☐ No☐

50	Have you ever drunk alcohol? *(If no, skip to question 55)*	Yes, currently ☐ No ☐ Yes but stopped during pregnancy☐ Yes but stopped before pregnancy☐
51	If you do drink alcohol during your current pregnancy, how often do you drink?	Daily ☐ 3-5 times a week ☐ Mainly on weekends ☐ Seldom (not weekly) ☐
52	If you do drink alcohol during your current pregnancy, on average how much alcohol do you drink per occasion (= per day that you do drink)? *(Serving = 1 glass wine, 1 tot spirits, 1 beer/cider/cooler)*	1-2 servings per occasion ☐ 3-4 servings per occasion ☐ 5 or more servings per occasion ☐ Seldom ☐
53	Do you usually drink alcohol:	With food / a meal☐ On an empty stomach☐ Before a meal☐
54	Do you usually eat less when you are drinking?	Yes ☐ No☐
55	Do you take any drugs? (recreational) *(If no, skip to question 59)*	Yes, currently ☐ No ☐ Yes, but stopped before pregnancy ☐ Yes, but stopped during pregnancy ☐
56	If yes currently, what type?	Tik ☐ Dagga ☐ Mandrax ☐ Other: ______________________
57	If yes, how often do you take the drug?	Many times a day ☐ Once a day ☐ 3-5 times a week ☐ Mainly on weekends ☐
58	Do you usually eat less when you are using drugs?	Yes ☐ No☐
	Family history	
59	Have any of the following family members had diabetes?	Mother ☐ Father ☐ Brothers ☐ Sisters ☐ No ☐
60	Have any of the following family members had gestational diabetes?	Mother ☐ Sisters ☐ No ☐

	Locus of control	
61	To which extent do you agree or disagree with the following statements about your own life:	
61.1	In your general work, you feel you have control over what happens in most situations	1.Strongly disagree☐ 2.Disagree☐ 3.Neutral☐ 4.Agree☐ 5.Strongly agree☐
61.2	You feel what happens in your life is often determined by factors beyond your control	1.Strongly disagree☐ 2.Disagree☐ 3.Neutral☐ 4.Agree☐ 5.Strongly agree☐
61.3	Over the next 5-10 years, you expect to have more positive than negative experiences	1.Strongly disagree☐ 2.Disagree☐ 3.Neutral☐ 4.Agree☐ 5.Strongly agree☐

61.4	You often have the feeling you are being treated unfairly	1.Strongly disagree☐ 2.Disagree☐ 3.Neutral☐ 4.Agree☐ 5.Strongly agree☐
61.5	In the past 10 years your life has been full of changes without you knowing what will happen next	1.Strongly disagree☐ 2.Disagree☐ 3.Neutral☐ 4.Agree☐ 5.Strongly agree☐
61.6	You gave up trying to better your life a long time ago	1.Strongly disagree☐ 2.Disagree☐ 3.Neutral☐ 4.Agree☐ 5.Strongly agree☐
	Eating behaviour – Cognitive restraint scale	
62	Do you deliberately take small helpings as a means of controlling your weight? (Do you have small servings at meals, to help control your weight?)	Definitely true☐ Mostly true☐ Mostly false☐ Definitely false☐
63	Do you consciously hold back at meals in order not to gain weight? (Do hold back the amount of food you eat at meals, on purpose, so that you don't gain weight?)	Definitely true☐ Mostly true☐ Mostly false☐ Definitely false☐
64	Do you not eat some foods because they make you fat	Definitely true☐ Mostly true☐ Mostly false☐ Definitely false☐
65	How frequently do you avoid "stocking up" on tempting foods? (How often do you stop yourself from keeping foods around home, that will tempt you to eat them?)	Almost never☐ Seldom☐ Usually☐ Almost always☐
66	How likely are you to consciously eat less than you want? (What are the chances that you will eat less than you want to, on purpose?)	Unlikely☐ Slightly likely☐ Moderately likely☐ Very likely☐
67	On a scale of 1 to 8, where 1 means no restraint (eating what you want, whenever you want it) and 8 means total restraint (constantly limiting food intake and never "giving in"), what number would you give yourself?	1-2 ☐ 3-4☐ 5-6 ☐ 7-8 ☐

	Uncontrolled eating scale	
68	When you smell a sizzling steak or a juicy piece of meat, you find it very difficult to keep from eating, even if you have just finished a meal	Definitely true☐ Mostly true☐ Mostly false☐ Definitely false☐
69	Sometimes when you start eating, you just can't seem to stop	Definitely true☐ Mostly true☐ Mostly false☐ Definitely false☐
70	Being with someone who is eating often makes you hungry enough to eat also	Definitely true☐ Mostly true☐ Mostly false☐ Definitely false☐
71	When you see a real delicacy (rare / expensive food), you often get so hungry that you have to eat right away	Definitely true☐ Mostly true☐ Mostly false☐ Definitely false☐
72	You get so hungry that your stomach often seems like a bottomless pit	Definitely true☐ Mostly true☐ Mostly false☐ Definitely false☐
73	You are always hungry so it is hard for you to stop eating before you finish the food on your plate	Definitely true☐ Mostly true☐ Mostly false☐ Definitely false☐
74	You are always hungry enough to eat at any time	Definitely true☐ Mostly true☐ Mostly false☐ Definitely false☐
75	How often do you feel hungry	Only at meal times Sometimes between meals Often between meals Almost always
76	Do you go on eating binges although you are not hungry?	Never☐ Rarely☐ Sometimes☐ At least once a week☐
	Emotional eating scale	
77	When you feel anxious, you find yourself eating	Definitely true☐ Mostly true☐ Mostly false☐ Definitely false☐
78	When you feel blue, you often overeat	Definitely true☐ Mostly true☐ Mostly false☐ Definitely false☐
79	When you feel lonely, you console yourself by eating	Definitely true☐ Mostly true☐ Mostly false☐ Definitely false☐
	Cravings	
80	Do you experience cravings during your current pregnancy?	Yes ☐ No ☐
81	If so, for what?	Specify:

	Eating pattern	
82	How many days per week do you usually eat:	Days /week:
	Before breakfast	
	Breakfast	
	Mid-morning snack	
	Lunch	
	Mid-afternoon snack	
	Supper	
	After supper	
	Wake up during the night to eat	

Dietary intake during the past month (before admission to hospital)

Think about the foods you ate and beverages you drank in the past month during your current pregnancy (before you were admitted to hospital). Tell me how many times per day or week or month you ate or drank the specific food item:

Food frequency	Only fill in one column			
		Times/		
	No	Day	Week	Month
Protein foods				
Red meat (beef, mutton, lamb), mince				
Organ meat: liver/ kidney etc.				
Fried fish				
Fish other (tinned/fresh/smoked)				
Fried chicken				
Chicken, with skin (roast, in stews, akni etc.)				
Pies, sausage rolls, samoosas, vetkoek, Gatsby				
Sausages: Vienna's, Russians, Boerewors				
Polony, cold meats, salami, tinned meat (bully beef)				
Eggs without fat (boiled/poached)				
Eggs with fat (scrambled, fried etc.)				
Dairy products				
Cheese (excluding cottage)				
Cottage cheese: full cream ☐ low fat ☐ fat free ☐				
Milk: full cream ☐ low fat ☐ fat-free ☐				
Yoghurt: plain/fat free/ artificially sweetened				
Yoghurt: normal/ low fat/ with fruit/ with sugar				
Fruit and Vegetables				
Fruit fresh (how many?)				
Fruit juice				
Vegetables (how many?) (Including stews) e.g. spinach, broccoli, butternut, squash, carrots etc				

Food frequency	No	Times/ Day	Week	Month
Fats				
Spread: Butter ☐ Margarine: hard ☐ tub ☐				
Oil: sunflower ☐ olive/ canola ☐				
Mayonnaise: normal ☐ lite ☐				
Starches				
Bread: white ☐ brown ☐				
Bread: whole wheat (high fibre)/Low GI/ Provita				
Oats or Maltabella porridge				
Maize porridge				
Cereals (high fibre) – eg. All bran, High Fibre Bran, Weetbix, Pronutro etc.				
Cereals (low fibre) – eg. Corn flakes, Rice Crispies, Special K etc.				
Rice, pasta, samp				
Potato (including stews etc)				
Potato fried/ chips (with fat)/ roti				
Legumes: Beans, lentils, soya etc.				
Extras				
Sweets: lollipops, hard boiled, soft, liquorice, jelly babies, super C's etc.				
Chocolate				
Jam/ syrup/ honey				
Sugar added to tea and coffee				
Sugar added in cooking				
Ice-cream, pudding, custard				
Nuts/ peanuts/ Peanut butter				
Cake/ tart/ muffin/ scone/ cookies/ sweet biscuits				
Savoury biscuits: salty cracks, cream crackers				
Rusks				
Crisps (simba, papas, pretzels)				
Cold drinks (carbonated): normal ☐ light/zero ☐				
Cold drinks (syrup mix): normal ☐ light ☐				
Take-away/ restaurant/street vendors				
Alcohol: Wine				
Beer/ Cider/ Cooler				
Spirits (vodka, brandy, whiskey)				

Appendix 3: Consent Form

Participant Information sheet

Investigation of the underlying, intermediate and modifiable risk factors for Gestational Diabetes development

Investigators: S Booley, J Harbron

Division of Human Nutrition, Faculty of Health Sciences, University of Cape Town

Dear Madam,

We would like to invite you to take part in a study for research. We are doing a study on the risk factors for diabetes that develops during pregnancy. From research we know that diabetes is a common disease in South Africa. In the case of diabetes that develops during pregnancy it can cause serious problems for both the mother and the baby.

We will need women who have been diagnosed with diabetes during pregnancy as well as women who were not diagnosed with diabetes. You can take part in this study if you are at least in your 28th week of pregnancy, have or have not been diagnosed with diabetes and are older than 18 years old. You may not take part if you were diagnosed with diabetes before your pregnancy.

What will be expected of you?

We would like to

- Measure your weight, height and waist circumference;
- Know about your physical activity and usual intake of certain foods;

- Know what medications you are currently on;
- Know about your weight history and certain socio-demographic information;
- Know if you have any diseases other than type 2 diabetes;
- Record some information from your folder such as your CD4 count, blood sugar, HbA1c, blood pressure and blood lipid levels.

This will take about 45 minutes of your time.

Risks and benefits of taking part in the study:

There are no risks in taking part in this study. There is no direct benefit from taking part in this study but this study could help us to identify common risk factors for gestational diabetes in the South African population

How will your confidentiality be protected?

Only the researchers in this study will know your personal information and your name will not be given to anyone (you will be allocated a code). Your study information will be stored in a computer database that can only be used by the study researchers. When any results are published, no names will be linked to any of the results.

Other important things that we would like you to know:

The Faculty of Health Sciences, Human Research Ethics Committee (REC) of UCT approved this study (REC REF: 111/2011 and REC REF 113/2011). This means that the research is ethical and that it is safe for any person to take part in the study. It also means that nobody is forced to take part in the study and that the research is done to international standards. Participation in this study is by your own free choice. You can change your mind about taking part in the study at any time without giving a reason and this will not affect your medical treatment in any way.

If you have any complaints regarding the ethics of this study or questions about your rights please do not hesitate to call the Human Research Ethics Committee of the University of Cape Town on 021 406 6338.

For any other questions regarding this study, please contact: Janetta Harbron or Sharmilah Booley on 021 406 6310/6769.

Informed Consent

Investigation of the underlying, intermediate and modifiable risk factors for Gestational Diabetes development

Investigators: S
Booley, J Harbron

Division of Human Nutrition, Faculty of Health Sciences, University of
Cape Town

Declaration of participant:

By signing below, I …………………………………………………. (Write your name and surname) agree to take part in this study and understand the procedures involved. All my questions have been answered to my complete satisfaction.

By signing this consent sheet I declare that I am taking part of my own free will, without being persuaded or pressured by another person. I realize I can withdraw at any time and that I do not have to give a reason to withdraw. I will follow the instructions of the research staff.

Place: ………………………………………………….. Date: ………………………..

Signature (of patient): ………………………………………………………………

Declaration of investigator:

I, …………………………………………………. (Name of researcher or her delegate), have fully informed the
above person of the procedures, aims and risks of the study, and answered all questions truthfully.

Signature (of fieldworker): ………………………………… Date: ……………………