SCHOOL OF HEALTH AND RELATED RESEARCH

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Thesis Title:

Association Between Dietary Patterns and Type Two Diabetes in Saudi Arabia

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Abstract

Background: Type 2 diabetes (T2D) is an endemic disease in Saudi Arabia affecting more than 10% of the population. However, there is limited evidence examining the association between diet and T2D among the Saudi population, particularly from the perspective of dietary patterns.

Aims: To identify dietary patterns among the Saudi population and to examine their association with T2D, HbA1c and Body Mass Index (BMI) levels.

Methods: Cross-sectional data from the 2013 Saudi Health Interview Survey (SHIS) and data collected from primary health patients were analysed. Factor analysis identified the dietary patterns for each data set and the relationships between diet, T2D, HbA1c and BMI levels were explored.

Results: Four dietary patterns were identified from the SHIS data: Traditional, Dairy Products, Seafood and Fast Food. After adjusting for age and sex, the Fast Food dietary pattern was associated with lower odds of a T2D diagnosis (OR=0.50, CI=0.44-0.57) and negatively associated with HbA1c level (*b*=-0.085, p=<0.001), whilst the Traditional dietary pattern was associated with higher odds of having undiagnosed diabetes (OR=1.062, CI=1.022-1.104) and was positively associated with HbA1c level (*b*=0.032, p=0.049).

Five dietary patterns were identified from the primary data: Comprehensive, Traditional, Fast Food, Snacking and Low Processed Food. After adjusting for age and sex, both Fast Food and Snacking were positively associated with HbA1c (*b*=0.182, p=0.007 and *b*=0.205, p=0.002 respectively) and after also adjusting for physical activity, Snacking was associated with higher BMI (*b*=0.142, p=0.044).

Conclusion: Dietary patterns that were more common in younger Saudis and included more fast food and calorie-dense snack foods are associated with higher HbA1c and BMI levels. A diagnosis of T2D was not associated with consistent differences in dietary patterns. This suggests there is scope to both reduce diabetes risk and improve management through dietary interventions. Development and evaluation of dietary interventions are now needed.

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List of Abbreviations

BMI: Body Mass Index

CASP: Critical Appraisal Skills Programme

CDC: Centres for Disease Control and Prevention

CI: Confidence Interval

DASH: Dietary Approaches to Stop Hypertension

EPIC: European Prospective Investigation into Cancer

FFQ: Food Frequency Questionnaire

HbA1c: Haemoglobin A1c (glycated haemoglobin)

IHME: Institute for Health Metrics and Evaluation

KMO: Kaiser-Meyer-Olkin measure of sampling adequacy

M: Mean

MENA: The Middle East and North Africa

MOH: Ministry of Health

NIH: National Institute of health

OR: Odds ratio

PCA: Principal Component Analysis

SAR: Saudi Ryals

SD: Standard Deviation

SE: Standard Error of the Mean

SHIS: Saudi Health Interview Survey

T2D: Type 2 Diabetes Mellitus

WHO: World Health Organization

Chapter 1: Introduction

The main aims of this thesis are to identify the dietary patterns within the Saudi population and to explore the relationship between dietary patterns and having a diagnosis of type 2 diabetes (T2D), body mass index (BMI) and with glycated haemoglobin (HbA1c) levels among individuals with and without a diagnosis of T2D in Saudi Arabia. However, to find if such evidence already exists, this thesis will first attempt to systematically explore the existing literature on the relationship between diet and T2D among the populations of Saudi Arabia and similar countries of the MENA region (the Middle East and North Africa). After that, this thesis will narrow its focus back to Saudi Arabia and attempt to achieve its aims through analysing data from the Saudi Health Interview Survey (SHIS) which contains information on health and several behaviours such as diet and analysing a primary cross-sectional survey undertaken to collect more detailed dietary data.

The second chapter of this thesis is a background chapter that will include general information about T2D epidemiology, pathophysiology and its relationship to obesity. It will also include information from different studies about the effect of diet on T2D when examined from the perspective of single dietary factors and dietary patterns. Furthermore, it will discuss the different methods used in research to approach diet, such as dietary patterns. Finally, it will discuss T2D status in Saudi Arabia and present the rationale for exploring the relationship between T2D and dietary patterns in Saudi Arabia. The background chapter will also present information regarding the current dietary recommendations to diabetic patients in Saudi Arabia.

The third chapter will present a systematic review that synthesises the current evidence about the relationship between T2D and dietary patterns in the Middle East and North Africa (MENA) regions. This review will identify gaps in the evidence base and provide a rationale for further primary research, particularly given the limited number of studies from Saudi Arabia.

The fourth chapter will discuss the methods used by the SHIS to collect their data and the methods used for the new primary data. The methods to be discussed in this chapter included study designs, locations of data collections, data collection instruments including FFQs, analysis plans, ethics and the sample size needed for the primary data. This chapter will also describe the methods used for data analysis including the factor analysis that identified the dietary patterns within the Saudi population.

The fifth chapter is the results chapter which will present both descriptive and inferential analysis of the SHIS data and the primary data. The dietary patterns of the Saudi population will be identified and the relationships between diet, other explanatory variables and HbA1c levels in individuals with and without a diagnosis of diabetes will be explored. The results of the analysis will help to improve our understanding of the relationship between diet and T2D in Saudi Arabia.

The sixth chapter is the discussion chapter. This chapter will describe the overall association between the identified dietary patterns and T2D among the Saudi population, will describe the demographic context for some of those dietary patterns and compare the results with previous similar research in the MENA regions. In addition, this chapter will provide a comparison for the result of the SHIS data analysis and the results of the primary data. This chapter will also discuss the weaknesses and strengths of this research and will describe possible implications for this research on future research and health policy and practice.

Chapter 2: Background

Diabetes is one of the non-communicable chronic diseases that causes a great burden for both individuals and health systems worldwide. Moreover, its rapid increase in prevalence in the Gulf States including Saudi Arabia makes it a significant public health threat to that region (1,2).

This chapter aims to provide general information about diabetes pathophysiology including its causal association with nutrition. Evidence will also be introduced linking diet as a significant risk for disease development and a key factor in its efficient management. Additionally, the disease burden will be discussed both globally and in Saudi Arabia. Finally, it will highlight the need to further explore the association between T2D and diet in Saudi Arabia.

2.1 Diabetes

2.1.1 Pathophysiology

Diabetes is a chronic disease that occurs if the pancreas cannot produce enough insulin (type 1) or if the body can't effectively utilise the produced insulin (type 2) increasing the levels of glucose in the blood (hyperglycaemia) (3). While type 1 appears early in life due to the destruction of Beta cells of the pancreas, type 2, in comparison, tends to appear later due to decreased insulin sensitivity, although it can affect both children and adolescents (4). Decreased insulin sensitivity will increase hepatic glucose synthesis and decrease peripheral glucose utilisation (5). In an attempt to maintain a normal glucose level, the pancreas will try to compensate by increasing insulin secretion, but with time, insulin secretion will decline resulting in impaired blood glucose levels that progress later into T2D (4,5).

The decline in insulin sensitivity, which leads to T2D, can occur if an individual has a disproportionate composition of muscle and fat. Insulin acting on fat cells will produce less glucose uptake in comparison with the muscle cells (myocytes). Thus obesity, particularly combined with a lack of physical activity which would increase glucose uptake, requires the pancreas to produce more insulin to maintain glucose homoeostasis (6).

There are many laboratory tests which can be used either to screen for or diagnose diabetes, including blood glucose level and haemoglobin A1c (HbA1c). While the blood glucose level will indicate the blood glucose level at the time of the test, HbA1c can show blood glucose level status for the past 2-3 months (7). When the level of glucose in the blood rises above normal, it starts to attach itself to the haemoglobin of the red cells creating the glycated haemoglobin (HbA1c).

2.1.2 Epidemiology

Over the past decades**,** there has been a significant increase in the incidence of T2D worldwide, which can be attributed to factors other than the genetic factors, considering that the genetic risk is relatively stable over time (8). Many studies have begun exploring new possible risk factors for T2D, and many of them have found a strong association between T2D and multiple environmental and lifestyle risk factors such as smoking, a sedentary lifestyle, unhealthy diet and obesity (8,9).

Diabetes had become a global burden; the World Health Organization (WHO) estimated that 422 million adults (8.5% of the adult population) are living with diabetes in its latest report on diabetes which was released in 2016 (10). In 2012, diabetes directly caused the death of 1.5 million adults and 2.2 million additional deaths from related conditions such as cardiovascular diseases (10).

Type 2 diabetes accounts for 90% of diabetes cases worldwide (2). Of those with T2D, 70% are from developing countries such as Saudi Arabia (2). The number of people with diabetes is expected to grow globally to be 592 million by 2035. Whilst globally the majority of patients will be diagnosed between 45 and 64 years old, there is an increase in the rate of T2D among children and adolescents associated with an increase in childhood obesity (2).

In addition to the health system burden, if not adequately treated and controlled, diabetes can represent a serious problem at the individual level as well. Diabetes is associated with severe complications such as stroke, heart disease, blindness, chronic renal failure, and lower-limb amputations due to diabetic foot complications (11).

Like other chronic non-communicable diseases such as hypertension, T2D aetiology is multifactorial including both genetics and lifestyle factors (12). Lifestyle risk factors associated with T2D include diet, obesity, smoking cigarettes, alcohol overconsumption and a sedentary lifestyle (8). Fortunately, unlike the genetic risk, many of the lifestyle risk factors, including diet, are modifiable.

2.2 Obesity as a risk factor for T2D

According to the WHO, obesity and overweight are defined as abnormal or excessive fat accumulation that represents a risk to health (13). The measure used to define overweight and obesity by the WHO, which is also the most common international measure, is the body mass index (BMI), calculated by dividing weight in kilogrammes by height in metres squared (13). According to the WHO definitions, an individual is considered obese if their BMI is above 30 kg/m^2 and overweight if their BMI is above 25 kg/m^2 (13). The excess fat accumulation is understood to be due to an imbalance between energy intake and expenditure (4).

The prevalence of overweight and obesity has tripled worldwide since 1975 (14). According to the WHO, the proportion of adults who are overweight was 39% in 2016, while the prevalence of obesity was 13% (14). The prevalence of overweight and obesity has also shown an increase in children and adolescents in both developing and developed countries (15).

The matching increase in the prevalence of obesity with the growth in the prevalence of T2D over the past decades highlights that overweight and obesity are a major risk factor for T2D. A behavioural risk surveillance system carried in the United States on self-reported body weight has estimated that the risk for T2D will increase by 9% for each kilogramme increase in body weight (4). Many recent clinical trials and observational studies have shown the importance of having an in reducing and maintaining body weight (16). For obese and overweight individuals, reducing body weight has been shown to improve glucose tolerance and insulin sensitivity and to decrease the risk of T2D (4).

Obesity can contribute to the development of diabetes by mechanisms of glucose intolerance, Beta-cell dysfunction and insulin resistance (17). Therefore, about 75% of the risk for T2D can be attributed to obesity (4). However, obesity itself is perceived as an imbalance between energy intake and expenditure. Thus, to control obesity, controlling diet has become the primary focus for many studies that aim to prevent and combat both T2D and obesity (4,5,18). Around 70% of patients with T2D are overweight or obese; therefore, a diet containing more energy relative to the expenditure can increase the risk for T2D not only by acting as a distinct risk factor but also by enhancing obesity (4).

2.3 Diet and T2D

Diet is believed to be a major factor in causing, preventing or controlling T2D. Hence there was an increased interest in identifying which dietary components or factors can contribute to or prevent T2D (4). The search for these components began with exploring diet from the perspective of macro- and micronutrients such as fat, carbohydrates, proteins, vitamins and minerals. Other studies have focused on single dietary components such as chips and carbonated beverages (19). More recent studies have begun to study diet from the perspective of dietary patterns such as the Mediterranean or vegetarian diets rather than just a single dietary factor or group (20).

2.3.1 Macro- and micronutrients and T2D

While studying diet as macro- and micronutrients, both the caloric amount and the composition of food are believed to be major determinants for glucose homoeostasis. The major groups of macronutrients are fat, carbohydrate, protein, and alcohol while the major groups of micronutrients are vitamins and minerals (5).

Fat

Dietary fat represents a heterogeneous group of fatty acids including saturated, trans-unsaturated, monounsaturated and polyunsaturated fatty acids (21). Many of the studies that have focused on a single type of fatty acids concerning T2D have produced inconsistent results (5). For the saturated fatty acids, however, epidemiological studies have shown a direct association to T2D and impaired insulin sensitivity (5). On the other hand, observational studies investigating the relationship between trans-unsaturated fatty acids and T2D have produced equivocal results (5). Large-scale observational studies examining the relationship of mono-unsaturated fatty acids to T2D have shown no association after adjustment for BMI (5). Other studies have found beneficial effects on insulin sensitivity from poly-unsaturated fatty acids coming from plant origin while for that coming from fish oils, the results were inconsistent (5).

In studying total fat in general, it has been demonstrated that long-term compliance with a low-fat diet (15% energy from fat) resulted in an improvement in glucose tolerance over five years (5). This result can be related either to the direct effect of fat on insulin sensitivity or to the fact that high fat intake can contribute to obesity. Thus, a low-fat diet can lower both glucose and insulin concentration while increasing glucose disposal.

A small-scale study, conducted on six healthy men in 2001, found that high-fat low-carbohydrate diets (83% fat, 2% carbohydrates) demonstrated an impairment of the ability of insulin to decrease the endogenous glucose synthesis and to favour glucose storage compared to medium (41% fat, 44% carbohydrates) and low-fat (0% fat, 85% carbohydrates) diets (21), thus suggesting incompatibility with individuals diagnosed with T2D. However, a larger-scale study examining high fat intake with insulin sensitivity among a sample of 1173 participants found no significant association. Nevertheless, after adjusting for BMI in the same sample, a high-fat diet was demonstrated to decrease insulin sensitivity for individuals who are obese, but not for those who are non-obese (22). This difference may be due to the difference in hyperinsulinemia between individuals who are obese and those who are non-obese. A study published in 2005 suggested that individuals with obesity usually have hyperinsulinemia which will result in more fat deposition and insulin resistance in response to a high-fat diet (23).

Carbohydrate

The glycaemic index is a measure that quantifies the glycaemic response to a standard amount of carbohydrates containing foods compared to the response produced by the same amount of glucose. Glycaemic load is a product of both the glycaemic index and the carbohydrate content of the food, and it is a better indicator of the quantity and quality of dietary carbohydrates. Foods such as white bread, rice and pasta that are relatively high on the glycaemic index and glycaemic load were observed to increase the risk for T2D in several studies (4).

Increased *dietary fibre* intake (e.g. cereal fibres) was found by some studies to be inversely associated with plasma insulin levels, and its increased consumption is observed to decrease the risk of T2D. Many mechanisms have been proposed to explain this effect including dilution of energy intake of other dietary components (4,5).

Resistant starch is found in foods such as legumes and cannot be absorbed as glucose, but instead, it is fermented in the colon to produce short-chain fatty acids such as butyrate. Resistant starches have been observed to decrease postprandial glucose and insulin levels in one meal laboratory-based studies (24) but, as in many cases of focusing on a single dietary component, the long-term studies have shown inconsistent results (4).

Some studies have produced evidence that low-carbohydrate diets can be effective for weight loss, which can be very useful for a patient who has been diagnosed with, or is at risk of developing T2D. This effect is understood to be due to eating an excessive amount of carbohydrates suppressing fat utilisation by utilising carbohydrates since it is preferred to be used by the body over other fuel types. This suppression can be due to the body's limitless storage capacity for fat compared to glucose and amino acids. Furthermore, glucose levels need to be maintained within narrow limits in the blood. Also, any excess glucose will eventually be converted to fat (the process of de novo lipogenesis), which contributes to obesity (23).

Nevertheless, in the third US National Health and Nutrition Examination Survey involving 12,000 individuals (1988-1994), no association was found between carbohydrate intake and plasma glucose, insulin and HbA1c. These findings helped to produce a consensus that the amount of overall carbohydrate intake is not a major risk factor for T2D (23). However, a study involving 2834 participants and collecting more details regarding food based on glycaemic index and load has shown that a diet that is high on the glycaemic index or rich in glycaemic load food is associated with increased insulin resistance and higher prevalence of the metabolic syndrome (25).

Protein

Although data on the effect of protein on T2D is relatively scarce, evidence from several studies has shown that protein consumption will not result in changes in the plasma glucose concentration (4). However, there are also studies that found evidence linking high intake of protein to T2D; for example, a 2016 study has concluded that participants who were in the highest quintile in their consumption of protein (both animal and plant-based) were found to have a 13% increased risk for T2D compared to those in the lower quintile (26).

Alcohol

Several studies have shown that heavy alcohol drinking is associated with insulin resistance while moderate to light drinking may improve insulin resistance (27,28). However, many observational studies have shown conflicting results on the effect of alcohol in the development of T2D (4). Nevertheless, there is evidence that links alcohol consumption to increased levels of BMI (29) which, in turn, is also a risk factor for T2D (30).

Micronutrients

Interest in micronutrients arises from the concept that increased oxidative stress is a contributing factor in the aetiology of diabetes. Although alpha-tocopherol improved glucose metabolism in animal studies, the findings are inconclusive in humans (4). Some observational studies have reported an association between low vitamin D and T2D while others have shown an adverse relationship between magnesium and T2D that is not seen in different studies after adjusting for other mineral and fibre intake (5). Although some of the micronutrients show effects on glucose and insulin metabolism, there is no clear evidence for the efficacy of their supplementation on the development of diabetes (31).

2.3.2 Dietary patterns and T2D

Examining the relationship of diet to chronic diseases using dietary patterns (combinations of foods and nutrients) rather than the traditional approach of focusing on specific nutrients or food groups has received increasing attention (20,32). More recently nutritional epidemiologists have proposed several reasons for using this approach. First, the complex combinations of food people usually eat are likely to be interactive or synergistic (20,32). Secondly, it is hard to examine the separate effect of many of the nutrients that are highly correlated (20,32). Also, the effect of single nutrients might be too small to detect in combination with the cumulative effect of multiple nutrients in a dietary pattern and analysis of individual nutrients can be confounded by the effect of dietary patterns (20).

Furthermore, in 2015, the USA Dietary Guidelines Advisory Committee has focused its recommendations on healthy dietary patterns rather than single dietary factors in its scientific report (33). This indicates how, increasingly, dietary patterns are used as a method to inform the public about dietary recommendations, rather than only offering advice about individual nutrients (32). In comparison, other countries such as Saudi Arabia continue to use the single dietary items approach for their dietary recommendations (34) which will be discussed in more detail in Section 2.5 of this chapter.

Methods for assessing dietary patterns

Characterising dietary patterns for a certain population can be done using several methods that can be categorised as investigator defined or data-driven. These two categories can also be used in combination (20,35).

Investigator defined (also called hypothesis-driven) dietary patterns are defined before the investigation. Dietary patterns can be examined by asking participants directly a yes/no question about their specific selective diet on the investigation (e.g. Are you a vegetarian?) or participants can be categorised based on an index or score system that shows their adherence to the diet under investigation (e.g. the Mediterranean diet) (36,37).

The data-driven approach defines dietary patterns after the collection of dietary data from the participants. It can be done using different methods including cluster analysis or factor analysis. In cluster analysis, dietary patterns are defined according to how participants cluster together based on their shared dietary behaviour. In factor analysis, dietary patterns are defined according to the correlation among foods which can be low, medium or high (37).

Comparison between hypothesis-driven and data-driven approaches have shown no superiority of one method over the other and either may be appropriate depending on whether the research aims to examine the levels of adherence to a specific dietary pattern of interest which has already been identified and defined, or to explore dietary patterns in populations where specific patterns of interest are not already defined (20,32,35).

Mediterranean diet as an example

One of the typical dietary patterns that has been studied is the Mediterranean diet (38). It comes, and hence is named, from observing the food habits of the population of the Mediterranean whose relatively good health was thought to be accounted for by their diet (38). Although there are around 20 different populations in the Mediterranean region, their diet has commonly shared characteristics (38). The Mediterranean diet is primarily plant-based; it is characterised by high consumption of vegetables, fruits, legumes, nuts, cereals; olive oil is the primary source for fat while fish, poultry and wine are consumed in low to moderate amounts and there is low consumption of red meat (38).

Multiple studies have explored the relationship of the Mediterranean diet to T2D (38). In a prospective cohort study involving 13,380 Spanish graduates who were followed for 4.4 years to detect the new onset of diabetes, participants who scored high in their adherence to the Mediterranean diet had an 83% lower risk of T2D (OR: 0.17,95% CI 0.04–0.72), compared to those who scored low (39).

For diabetic control and management, patients who scored high in their adherence to the Mediterranean diet had significantly lower 2-hours post-meal glucose levels compared to those who scored lower (difference: 2-hours glucose, 2.2 mmol/L, 95% CI 0.8–2.9 mmol/L, p <

0.001) (25). Also, the mean HbA1c concentration was lower (38) demonstrating that, in the longer-term, individuals who had higher adherence to the Mediterranean diet had fewer episodes of hyperglycaemia.

2.3.3 Summary of evidence linking diet and T2D development

In conclusion, studying the relationship between diet and T2D has changed over time. After focusing on macro- and micronutrients, many studies attempted to find the relationship between T2D and diet by focusing on single dietary factors such as meat, whole grain or fruit (8). However, those approaches have been proven to be difficult and to produce inconsistent results most of the time due to the complex nature of the diet itself and the interaction between different dietary components (8). Therefore, more recent studies examine the relationship between T2D and diet by focusing on dietary patterns, rather than just macro- and micronutrients or a single dietary factor (8,18,23).

2.4 Reversing type 2 diabetes

As T2D pathophysiology involves having abnormal insulin sensitivity and hyperglycaemia, research suggests that it is possible to reverse hyperglycaemia if insulin sensitivity is restored to normal (3,40). It has been observed that interventions that dramatically decrease the total caloric intake of T2D patients such as having bariatric surgery or decreasing food intake to have negative caloric balance lead to a major decrease in liver and pancreatic fat content and normalization of their insulin sensitivity which results in decreasing the fasting blood glucose levels to normal levels even if muscle insulin sensitivity is not fully restored to normal (40,41).

The hypothesis that using dietary caloric restriction alone can reverse T2D was tested by a study published in 2011 where both T2D patients and non-diabetes controls were limited to only 600 kcal/day (41). In this study, a study sample of 11 individual with diagnosed T2D and a mean age of 49.5 years (SD=2.5 years) was recruited for this study. The 11 participants had a mean BMI of 33.6 kg/m^2 (SD=1.2 kg/m^2) and their measurement for their hepatic glucose output, beta-cell function and peripheral insulin sensitivity were taken both at baseline and after 7 days of restricting their diet to only 600 kcal/day. After 7 days, participants fasting plasma glucose normalised, insulin suppression of hepatic glucose increased, hepatic triacylglycerols decreased and the insulin response increased, whilst there was a decrease in liver fat by up to 30% (41).

The potential for dietary interventions to reverse T2D was also supported by a randomized clinical trial that aimed to provide evidence that reducing body weight through primary care intervention can reverse hyperglycaemia among T2D patients to the point where no medication is needed (42). The clinical trial was carried out between 2014 and 2017 in which 306 participants were recruited for both the intervention and control groups (42). The clinical trial achieved a 46% remission rate for the intervention group with an average weight loss of 10 kg for each participant over the interventions period which lasted for around 3 years (42). Thus, recovering the pancreatic beta-cell function even in some patients with long-lasting T2D condition where the beta-cell dysfunction was previously believed to be irreversible(43). This provides further supporting evidence that dietary intervention can help to control and reverse T2D condition (42).

2.5 Saudi Arabia

Diabetes is endemic in Saudi Arabia (44). In 2013, the prevalence of diabetes among adults aged 20-79 years was estimated to be 20.2% after adjustment for the Saudi population's age and gender (45). This represents an increase compared to the rates in 2000 when the prevalence was 17.7% in men and 16.4% in women (11). This increase can be attributed to multiple risk factors, including genetics and diet. Furthermore, The results from a 2013 Saudi national health survey have shown the prevalence of diabetes to be 7.8% in the age group 25-34 and to increase to 50.6% among the 65 or older age group (46).

2.5.1 Health system development in Saudi Arabia and the 2013 national health survey

Saudi Arabia has undergone a remarkable development in all sectors including its health system over the past 50 years (11). Although there was a major improvement in the health system and health in general, changes in lifestyles following the modern trends towards unhealthy dietary patterns, and reductions in physical activity have led to a fast epidemiological transition in the trends of disease from communicable to non-communicable chronic diseases such as diabetes (11,47). Saudi Arabia is among the countries that have the highest prevalence of T2D and obesity in the world (11). Moreover, the International Diabetes Federation has reported Saudi Arabia among the top 10 countries with the highest prevalence of diabetes among adults aged 20 to 79 years (48).

During this period of fast changes, there was also an increase in the prevalence of tobacco smoking in Saudi Arabia as well (49). This risk factor has contributed to the growing prevalence of chronic disease, including T2D in Saudi Arabia (49).

Lack of physical activity among the Saudi population is not the result of their recent changes in lifestyle only. There is also a lack of community amenities in Saudi Arabia which can encourage people to do physical activities such as public gardens, recreational and sports centres within neighbourhoods (49).

2.5.2 Type two diabetes in Saudi Arabia

In 2013, the Ministry of Health (MOH) of Saudi Arabia with the help of The Institute for Health Metrics and Evaluation (IHME) carried out a national Saudi health interview survey (SHIS) that aims to measure chronic diseases in Saudi Arabia and their associated risk factors (46). Furthermore, the SHIS questionnaire has included questions about 18 food items (fruits, juices and smoothies, vegetables, dark meat fish (like salmon), and non-dark meat fish, red meat, poultry, shrimp, processed meat, processed food, eggs, nuts, milk, laban, yoghurt, labneh, cheese and carbonated drinks with no distinction regarding their sugar content) (46).

In 2013, the SHIS found that approximately 1 million men and 0.7 million women were diabetic in Saudi Arabia based on the results of HbA1c testing and self-reporting of a diagnosis of diabetes. The prevalence of diabetes among the 2013 sample has shown an increase with age as expected. Prevalence is 4.7% and 7.8% in the youngest age groups of 15-24 and 25-34 respectively, increasing to 50.6% among the age group 65 or older (46). The total prevalence of diabetes across this sample was found to be 13.6% (46). However, a global study examining the prevalence of diabetes worldwide has found that after adjusting for the national population's age and gender, the prevalence of diabetes in Saudi Arabia was 24% in 2013 (50). This global study used data sources collected from various Saudi studies prior to the 2013 national health survey and additionally the prevalence found by those prior Saudi studies was adjusted by the global study for the Saudi population, thus, ranking Saudi Arabia 7th among the countries with top prevalence of diabetes in the world (50). Section 6.4.1 of the discussion chapter will discuss in more detail the applicability of these figures to the Saudi population.

In 2014, a study about the diabetes epidemic in Saudi Arabia was published using the data acquired from the SHIS in 2013 (51). In this study, individuals were considered diabetic if they had an HbA1c level of 6.5% or higher, or if the respondent reported taking medication for diabetes (51). Those who had an HbA1c level of less than 6.5% but more than 5.7% and did not report taking medication for diabetes were considered borderline diabetic (prediabetes) in this study. Although many may consider the borderline level of HbA1c would be 6-6.5%, in this study it was expanded to start from 5.7%, probably, because T2D is common in Saudi Arabia (51). Knowing that these levels are arbitrary and the cut off points may change from population to population, they may have chosen to expand it to include 5.7% possibly because diabetes is an endemic disease in Saudi Arabia with high prevalence and so it is important to identify those at increased risk for T2D at earlier stages. Based on these criteria for diagnosis, both type 1 and type 2 prevalence were found to be 13.4% of the total survey sample but only 8.5% reported a diagnosis of diabetes (51). This suggests that about 4.9% of the survey population had undiagnosed cases of diabetes. This relatively high percentage of undiagnosed cases can be explained by knowing that Saudi Arabia is one of the top ten countries in diabetes prevalence (50). Furthermore, it had been found that about 15.2% (adjusted to the Saudi population's age and gender distribution) are in the range defined as prediabetes (51). This is without a doubt an alarming percentage knowing that the Saudi population is relatively young. However, this percentage was based on defining borderline diabetics as those who have an HbA1c level of 5.7-6.5%. Expanding the range from 6-6.5% per cent will have increased the reported prevalence of borderline diabetes compared to studies using a higher threshold.

Another study based on the SHIS data was published in 2015 focusing on Saudi women's health. This study has found that 35% of women were obese, with 28% being overweight among the survey sample (52). This study also found the prevalence of diabetes among Saudi women to be 11.7% (52). This percentage has shown an increase with age which is expected for diabetes (52). However, almost half of the diabetic women (48.4%) were undiagnosed diabetics (52). This may be explained by the fact that women have a higher prevalence of obesity and lower levels of physical activity in comparison to men. It is possible also that lack of public transport and the fact that women were not allowed to drive until recently in Saudi Arabia may have limited the access of some of the Saudi women to health care and therefore increased their percentage of undiagnosed diabetes.

2.5.3 Diet in Saudi Arabia

A case-control study examining the association between T2D and diet as single food items was done in Al-Qasim region in Saudi Arabia in 2010. The study found that consuming more kabsa (meat and rice-based dish), dates, fish, bakery items and potato chips (chips) were associated with higher odds of having T2D while consuming more vegetables was associated with lower odds of having T2D (47).

Using the SHIS, there was one study that focused exclusively on fruit and vegetable consumption among adults and it was published in 2015 (53). The study concluded that only 2.6% (53) of the survey sample met the US Centres for Disease Control and Prevention (CDC) guideline for the daily consumption of fruits and vegetables which is estimated as eating 2-3 cups of vegetables and 1.5-3 cups of fruits per day (54). The likelihood of meeting the CDC criteria was higher among older age groups (53). However, this low percentage suggests health authorities need to consider further measures that can improve the Saudi population's diet in general by encouraging healthier choices.

In addition to the previous study, another study used the SHIS data and was focused exclusively on diet and was published in 2016 (55). In this study, it was stated that the serving size for many items was not clarified on the survey manual; therefore, this was estimated using guidelines from the US Department of Agriculture. Thus, the 2016 study used sources that were not made specifically for the Saudi population to estimate average serving size. By doing this, there is a risk that this result might be less generalisable to the Saudi population.

At first, this study presents the frequency of consumption for 18 food items that were included in the SHIS for the whole population in general. It shows that the highest consumed beverage in volume in Saudi Arabia was laban, with a consumption of 219 ml per person per day on average (55). Laban is a traditional thick yoghurt drink which is usually made using cows', goats' or camels' milk and contains 60 Kcal per 100 ml which is similar to regular whole milk (56). Since the survey does not ask specifically about coffee or tea, this explains why laban was reported to be the most consumed drink in Saudi Arabia. Regarding foods, the highest consumed food item in weight in Saudi Arabia was vegetables, with 111 grams consumed per person per day on average (55). There are many other food items that are considered main components in the traditional Saudi diet such as bread and beans but the SHIS did not include them as items in their FFQ.

The 2016 SHIS data diet study also explores the relationship between the frequency of the consumed 18 items and sex, age group, the level of education and the level of income (55). Regarding sex, it shows that the unadjusted consumption of fruits, red meats, processed food, eggs and carbonated beverages (with no distinction regarding their sugar content) were statistically higher in males compared to females. On the other hand, yoghurt and cheese consumption was statistically higher in females compared to males. Regarding age groups, the study found that younger age groups consumed more processed meat, processed foods and sugary beverages while the older age group consumed more laban. This can be explained by knowing that laban is a more traditional drink than the relatively new carbonated beverages. Concerning education, people with a higher education level consumed more fruit, shrimp, labneh and cheese. Similarly, people with a higher income showed more frequency of consumption for fruits, shrimp, red meat and labneh. Since people with high education usually also have a higher income, this can explain the similarities in trends between the level of education and the level of income concerning frequency of consumption.

2.5.4 Obesity in Saudi Arabia

As with T2D, the prevalence of obesity has also increased with the change of lifestyle in Saudi Arabia (57). The prevalence of obesity among adults in Saudi Arabia increased from 22% in 1992 to 28.7% in 2013 (57,58).

A study was published in 2014 using the 2013 SHIS data, in which the focus was obesity (58). This study has found that about 28.7% of the survey sample was obese (58). Furthermore, it has been found that obesity was more prevalent in women compared to men (33.5% vs 24.1%) (58). This may be explained by women adopting a more sedentary lifestyle given the extremely hot weather and culture of Saudi Arabia which rarely encourage physical activities for women.

2.6 Nutritional guidelines for diabetes management in Saudi Arabia

The Ministry of Health in Saudi Arabia has established a national diabetes management and prevention programme that aims to help in controlling diabetes by increasing awareness about diabetes and providing guidelines for diabetic patients including dietary guidelines (34). The dietary guideline includes several recommendations about the choice of food items and cooking methods.

For food items, the guideline recommends choosing dairy products that have low or no-fat while avoiding full-fat products or cream cheese. It also recommends having lean meat and ground meat that have less fat while avoiding processed meat. Concerning wheat, the guideline recommends choosing whole-wheat products such as brown bread. For vegetables and fruits, it recommends avoiding canned products while eating fresh or frozen products, probably in order to avoid unhealthy added products such as salt and sugar. There were no specific recommendations regarding portion sizes. It also recommends avoiding fruit drinks with added sugar (34).

For cooking, the guidelines recommend not to use cooking methods such as frying or microwaving (possible because it is used mainly for processed food) and to use other cooking methods such as grilling, boiling and steaming. It also recommends using less salt or fatty products in cooking than usual and replacing them when possible. Furthermore, the guidelines recommend using vegetable oils rather than lard or butter. In the case of baking, the guideline recommends using whole wheat flour (34).

This guideline for diabetic patients reflects an emphasis on modifying diet from the usual perspective of single dietary items rather than food patterns.

2.7 Conclusion

While many studies have focused on the genetic factors, which are well-established and relatively stable over time, studies that focus on the relationship between T2D and diet in Saudi Arabia are very limited and most only focus on specific dietary components.

Only a few studies have examined the relationship between diet and T2D in Saudi Arabia, and they focused on single dietary factors such as kabsa and bakery items (9,47). Therefore, the next chapter will concentrate on investigating dietary patterns rather individual dietary factors among the Saudi population and other similar populations through a systematic review. This may help to explain the increase in the prevalence of T2D in Saudi Arabia and add to our current knowledge regarding T2D and dietary patterns.

2.8 Background chapter summary

Type two diabetes (T2D) is a non-communicable chronic disease that increasingly causes a great burden on individuals and health systems due to its high morbidity (2). As is the case for most chronic diseases, T2D aetiology is multifactorial where both genetics and diet can predispose an individual to T2D. Nutrition is a known non-genetic risk factor for T2D (59).

Researchers begin investigating the link between diet and T2D from the simple perspective of macro- and micronutrients (such as carbohydrates) or from the perspective of single food items (such as the date fruit) (5,60). However, the inconsistency in many of the results highlighted how complex and interlacing diet is. Therefore, researchers began examining the relationship between T2D and diet as a whole and as dietary patterns (61).

Saudi Arabia is known to be endemic for T2D (50). The genetic risk factor for T2D in Saudi Arabia is well established; however, there is little evidence examining the link between T2D and diet in Saudi Arabia, particularly, from the perspective of dietary patterns. Therefore, it is not unexpected that the MOH of Saudi Arabia provided dietary guidelines for T2D patients that are based only on modifying diet as single food items rather than dietary patterns (34). Due to the paucity of evidence, more research is needed to examine the association of T2D with dietary patterns in Saudi Arabia.

Chapter 3: A systematic review of evidence for associations between dietary patterns and diabetes in MENA regions

3.1 Introduction

The aim of this chapter is to summarise and discuss the current evidence from the literature about the relationship between T2D and dietary patterns in MENA regions before attempting to do further primary research focused on Saudi Arabia. Due to the limited number of studies about T2D and dietary patterns in Saudi Arabia and to include enough evidence in this systematic review, the scope was expanded to include all studies from the MENA regions where the food culture is relatively similar.

Summarising the current evidence for the relationship between T2D and dietary patterns in the MENA regions will help to identify the common dietary patterns of these regions. It will also help to explore which of the dietary patterns are more or less associated with T2D. Finally, it will help to identify if further research is needed to explore specifically the relationship between T2D and dietary patterns in Saudi Arabia.

3.2 Methods

This systematic review focuses on the studies that examine the relationship of dietary patterns to T2D in the MENA regions. In this section, I will discuss the methods for this systematic review under three main headings: search strategy, methods of data extraction and the quality assessment process for included studies. Furthermore, the search strategy can be explained under two subheadings: inclusion criteria and search method. In addition, two methods of data extraction will be described.

3.2.1 Search strategy

Inclusion criteria:

There were five inclusion criteria for this systematic review: 1) the study must be a primary study, 2) it must be from the MENA region, 3) the study must have well-defined dietary patterns as an exposure factor, 4) it must have the diagnosis of T2D or one of the measures used to diagnose or monitor diabetes as an outcome, and 5) it must be published in English. Since medical education in MENA countries is done mainly in the English language, it is expected that all relevant literature will be published in English.

The exclusion criteria include reviews and primary studies that did not define the diet according to dietary patterns, studies that did not include having T2D or included at least one blood test for glucose haemostasis in its outcomes.

Search method:

To find the relevant literature, two major search engines were used: PubMed through Ovid and Web of Science. The searches using both engines were conducted using the same comprehensive set of keywords and their combinations (Table 3.1). To find additional relevant studies, all the references and citations (as identified by Google Scholar) of potentially relevant studies identified by the systematic searches were also reviewed. All searches were also carried out in May 2020 to identify any newly published studies; however, no additional studies that fit the inclusion criteria for this systematic review were found.

Table 3.1: Keywords used for searches in PubMed and Web of Science and their combinations

Concept	Terms
Outcome	diabetes mellitus, type 2/ or hyperglycemia/ or glucose intolerance/ or hyperinsulinism/ or insulin resistance/ or metabolic syndrome x/
	And
Exposure	diet/ or diet, diabetic/ or diet, atherogenic/ or diet, carbohydrate-restricted/ or diet, fat-restricted/ or diet, high-fat/ or diet, Mediterranean/ or diet, paleolithic/ or diet, protein-restricted/ or diet, vegetarian/ or diet, western/ or ketogenic diet/ food habits/ or food preferences/
	And
Region	Middle East/ or Bahrain/ or Iran/ or Iraq/ or Israel/ or Jordan/ or Kuwait/ or Lebanon/ or Oman/ or Qatar/ or Saudi Arabia/ or Syria/ or Turkey/ or United Arab Emirates/ or Yemen/ Africa, Northern/ or Algeria/ or Egypt/ or Libya/ or Morocco/ or Tunisia/ Djibouti/ or Somalia/ or Sudan/ or MENA/ or North Africa/

3.2.2 Data extraction

To summarise the results of the studies, two methods of data extraction were used. The first method compared methods and results of the individual studies as reported, while the second method compared associations with dietary patterns, after grouping similar patterns identified across the included studies.

The first method of data extraction:

The first method summarised all the studies identified by this systematic review in a data extraction table (Table 2) that allows for facilitated viewing and comparison between individual studies. The variables in Table 2 include study year and main author, region, sample type and size, the method for identifying dietary patterns, dietary patterns studied, methods of statistical analysis, results and the outcome of the study.

The second method of data extraction

The second methods summarise the results from the identified studies in this systematic review by grouping the similar dietary patterns to allow easy comparison between dietary patterns across all identified studies (Table 3). The main components of each dietary pattern and their main outcome will also be identified in this data extraction method. Due to the non-standardised methods of data collection and analysis among the 11 studies, pooling the data for meta-analysis could result in misleading results.

3.2.3. Quality assessment process

The identified literature included in this systematic review comprised four types of study design: clinical trials, cohort studies, case-control studies and cross-sectional studies.

The quality of clinical trials, cohort, and case-control studies was assessed using checklists obtained from The Critical Appraisal Skills Program (CASP) (62). Both checklists for clinical trials and case-control studies contain 11 questions of which nine can be answered by "yes", "no" or "can't tell", while the other two are general questions about the results. The checklist for cohort studies contains 12 questions of which nine can be answered by "yes", "no" or "can't tell", while the other three are general questions about the results. The quality assessment score for all the studies was dependent on nine yes/no questions which consist of general and detailed questions about the validity and generalisability of the assessed study results.

The quality of cross-sectional studies was assessed using the quality assessment tool for observational cohort and cross-sectional studies obtained from the US National Institute of Health (NIH) (63). The checklist contains seven questions after excluding the questions not applicable to cross-sectional studies. The questions can be answered by "yes", "no", "can't determine” or “not reported”. The questions are about the clarity of the objective of the study, specifying the study population, estimates of the sample size and power, measurement of exposures and outcomes, and controlling for confounding factors.

3.3 Results

3.3.1. The search results

The search in PubMed through Ovid yielded 154 studies while the search in Web of Science yielded 1,182 studies. After screening titles, 1,311 studies were excluded. The remaining 57 studies were used for additional reference searches and citation searches in Google Scholar. Nine potential additional studies were identified through screening of reference lists and citations. After assessing the full text for eligibility, only 12 studies met all the inclusion criteria (Figure 3.1).

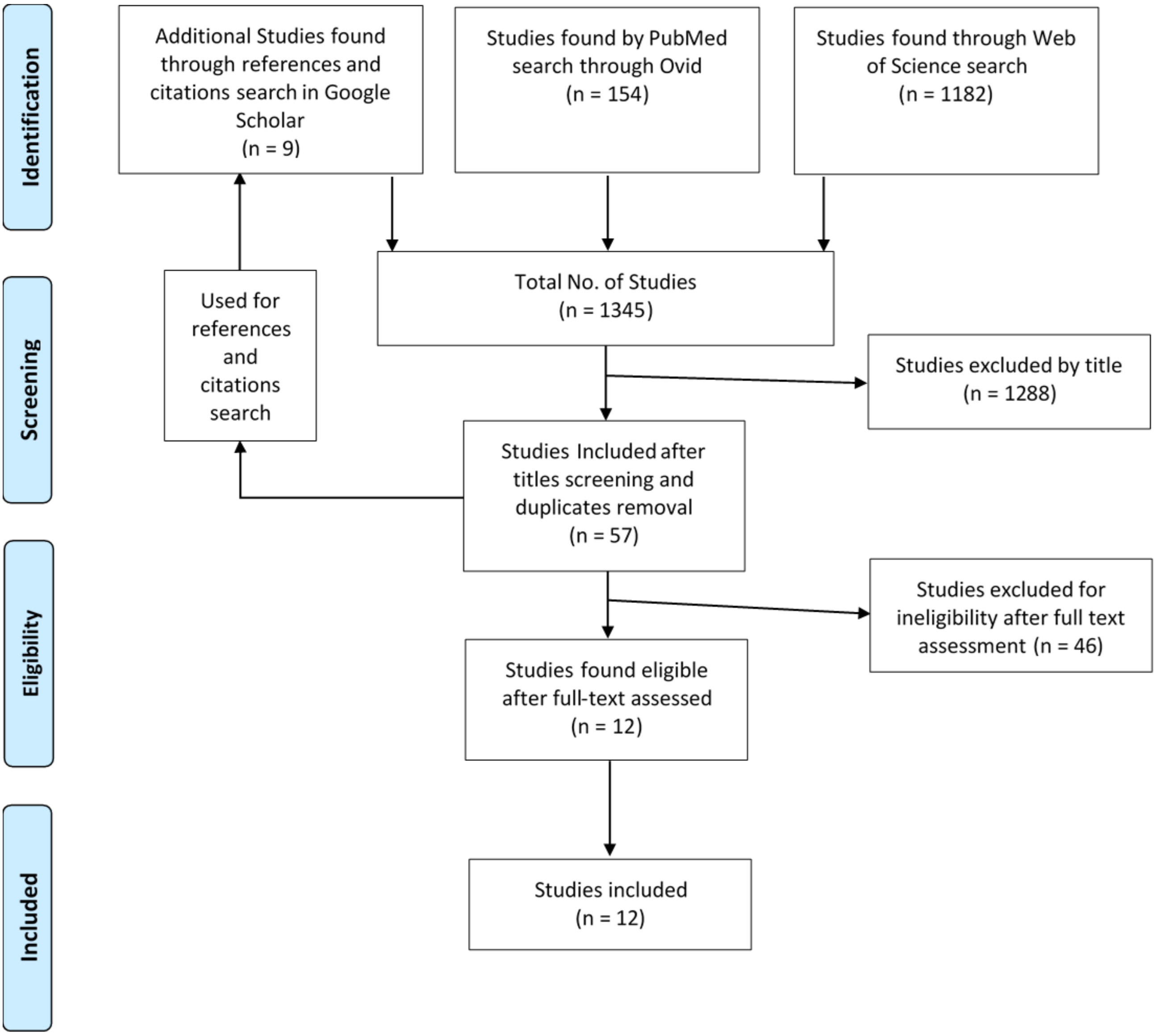

Figure 3.1: Flow diagram of the systematic review search results

3.3.2 The first method of data extraction

A summary of the characteristics of each study, the analysis and results of the dietary patterns can be found in Table 3.2. The 12 studies included in this systematic review were published between 2007 and 2016 and a total of 38 dietary patterns were analysed. Seven of the studies were based in Iran, two in Lebanon, one in Israel, one in Algeria and one in Saudi Arabia. Seven of them were cross-sectional studies, two of them were case-control, another two were clinical trials and one was a cohort study. Seven of the studies have a significant result that indicates either positive or negative association between the dietary pattern and T2D or having abnormal glucose blood tests; however, four did not identify statistically significant associations between dietary variables and the outcome measures.

3.3.3 The second method of data extraction

For a better comparison between the 33 dietary patterns of the 12 studies, similar dietary patterns have been grouped resulting in five distinct dietary patterns: “Fast Food”, “Traditional”, “high protein”, “healthy” and “fruit” predominant dietary patterns. The Fast Food dietary pattern is characterised by a high intake of easily prepared processed food usually served by restaurants such as sandwiches, pizza, French fries, desserts and sugar-sweetened carbonated beverages. The Traditional dietary pattern is characterised mainly by high intake of full-fat dairy products, legumes, fruits, eggs and some of the studies also included red meat in this dietary pattern. The high protein dietary pattern is characterised by a high intake of red meat, eggs, non-fried fishes, alcohol and chicken. The healthy dietary pattern is characterised mainly by a high intake of low-fat dairy products, vegetables, fruits, fish and poultry. The fruit predominant is characterised by a high intake of fruits compared to other items.

The components and outcomes of the six grouped dietary patterns can be found in Table 3.3. Three of the grouped dietary patterns (recommended approaches to control diabetes or hypertension, healthy and Traditional) were negatively associated with T2D or hyperglycaemia (abnormally higher levels of blood glucose) while one (Fast Food) was positively associated with T2D or having hyperglycaemia. The other two (high protein, fruit predominant) had only non-significant results; nevertheless, the high protein pattern had a consistently positive association with T2D while the fruit predominant had inconsistent results.

3.3.4 Quality assessments results

Only two studies among the cross-sectional type scored as low as 5/7 and one clinical trial scored as low as 7/9. The two cross-sectional studies scored low because they did not examine the outcome concerning different levels of adherence to the dietary patterns. The clinical trial scored low because, among the 84 participants, only 36 completed the trial and the others were not accounted for and no reasons for loss of follow-up were provided.

Table 3.2: Description of the studies identified by the systematic review

Study No.	First author and year	Region	Study design	Sample size and type	Method for identifying dietary patterns	Dietary patterns Studied	Analysis used	Results	Outcome	Study Quality
1	A. Elhayany, 2010 (64)	Israel	Clinical trial	259 overweight diabetic patients recruited from 10 primary health clinics, aged 30-65 years with a mean age of 55 years. 179 of them completed a 12-month follow-up.	Investigator defined	*low-carbohydrate Mediterranean **Traditional Mediterranean ***2003 American Diabetic Association diet	Generalised linear model analysis describing the 12-month changes in fasting blood glucose and HbA1c	**Fasting blood glucose in mmol/l (+-SD)** *baseline:10.26 (1.69) 12 months:7.19 (1.85) **baseline:10.07 (1.80) 12 months:6.57 (1.34) ***baseline:10.47 (2.00) 12 months:6.18 (0.84) p=<0.001 **HbA1c in % (+-SD)** *baseline:8.3 (0.8) 12 months:6.7 (0.9) **baseline:8.3 (1.0) 12 months:6.5 (0.8) ***baseline:8.3 (1.0) 12 months:6.3 (1.4) p=<0.001	Both Traditional Mediterranean and low-carbohydrate Mediterranean diets induced a greater decrease in fasting blood glucose and HbA1c than did the American Diabetic Association diet.	8/9
2	Parvane Saneei, 2015 (65)	Iran	Cross-sectional	420 Isfahani female nurses randomly selected from seven hospitals, more than 30 years old	Investigator defined and diet score	Dietary Approaches to Stop Hypertension (DASH diet)	Odd ratio of abnormal glucose homoeostasis among the lowest and highest adherent group of the diet	Multivariable adjusted: 0.71 (0.21–1.84), p= 0.38	There was not enough evidence to conclude that adherence to the DASH diet was associated with higher or lower odds of having abnormal glucose homoeostasis.	6/7

Study No.	First author and year	Region	Study design	Sample size and type	Method for identifying dietary patterns	Dietary patterns Studied	Analysis used	Results	Outcome	Study Quality
3	F. Naja, 2013 (66)	Lebanon	Cross-sectional	323 adults randomly selected from the general population, 18 years or older with no history of chronic disease	Exploratory Factor Analysis	*Fast Food/Dessert **Traditional Lebanese ***High Protein	Odds of Hyperglycaemia assessed by multivariate-adjusted logistic regression	* 3.81 (1.59–9.14), p= 0.001 ** 1.44 (0.67–3.08), p=0.31 *** 1.60 (0.70–3.62), p=0.70	Higher adherence to Fast Food/dessert dietary patterns were associated with higher odds of having hyperglycaemia. There was not enough evidence to conclude that Traditional Lebanese and high protein diets were associated with higher or lower odds of having hyperglycaemia.	6/7
4	Nasrin Darani Zad, 2015 (67)	Iran	Cross-sectional	400 T2D patients, 40–60 years old with no history of chronic disease other than T2D	Exploratory principal component factor analysis	*Vegetable & Poultry **Western ***Semi-healthy	Regression coefficient for abnormal HbA1c and fasting blood glucose	**HbA1c:** *b= -.007 (95%CI=-.013-.000) **b=-.0003 (95%CI=-.099-.099) ***b=.071 (95%CI=-.028-.171) **Fasting blood glucose:** *b=-.002 (95%CI=-.005-.000) **b=.014 (95%CI=.024-.003) ***b=-.003 (95%CI=-.005-.000)	There was not enough evidence to conclude a relationship between HbA1c and all dietary patterns. There was a positive association between Western dietary pattern and abnormal fasting blood glucose but not enough evidence to conclude an association between fasting blood glucose and the other dietary patterns.	5/7

Study No.	First author and year	Region	Study design	Sample size and type	Method for identifying dietary patterns	Dietary patterns Studied	Analysis used	Results	Outcome	Study Quality
5	F. Naja, 2012 (68)	Lebanon	Case-control	58 T2D patients and 116 controlled from the general population, older than 18 years of age	Exploratory Factor analysis	*Refined grains & desserts **Traditional Lebanese ***Fast Food ****Meat & Alcohol	Odds ratios of having T2D	*3.85 (1.31–11.23) **0.46 (0.22–0.97) ***2.80 (1.41–5.59) ****1.43 (0.83–2.46)	Refined grains & dessert and Fast Food diet were associated with higher odds of having type 2 DM while Traditional Lebanese diet was associated with lower odds of having T2D. There was not enough evidence to conclude an association between meat & alcohol diet and T2D.	8/9
6	A.M Fathia Khogali, 2013 (69)	Saudi Arabia	Cross-sectional	170 diabetic patients recruited from a hospital, 30-79 years old in age	Exploratory Factor analysis	*Transitional dietary pattern **Healthy pattern ***Desirable fat pattern ****Traditional pattern *****Mousselines pattern ******Snackings pattern	Linear regression for glucose, postprandial glucose and HbA1c blood levels	**Glucose:** *r=0.703(p=0.0001) **r=-0.661(p=0.0001) ***r=-0.514(p=0.03) ****r=-0.673(p=0.0001) *****r=-0.389(p=0.063) ******r=0.13(p=0.145) **Postprandial:** *r=0.662(p=0.001) **r=-0.391(p=0.062) ***r=-0.348(p=0.07) ****r=--0.347(p=0.07) *****r=-0.008(p=0.914) ******r=-0.105(p=0.173) **HbA1c:** *r=0.689(p=0.0001) **r=-0.574(p=0.014) ***r=-0.589(p=0.008) ****r=-0.558(p=0.020) *****r=0.013(p=0.862) ******r=0.055(p=0.477)	The transitional pattern was positively associated with higher levels of glucose, postprandial glucose and HbA1c levels. The healthy pattern, desirable fat patterns and Traditional pattern were negatively associated with glucose and HbA1c levels. There was not enough evidence to conclude any other relationship between the biochemical indexes and dietary patterns.	5/7

Study No.	First author and year	Region	Study design	Sample size and type	Method for identifying dietary patterns	Dietary patterns Studied	Analysis used	Results	Outcome	Study Quality
7	Marsa Zaroudi, 2016 (70)	Iran	Case-control	111 newly diagnosed cases of T2D and 222 controlled, aged 43-77 years	Factor analysis with the principal component	*Healthy **Transitional ***Traditional	Odds ratios for having T2D	*1.18 (0.56–2.46) **2.17 (1.0–4.50) ***2.13 (1.03–4.41)	Both transitional and Traditional dietary patterns were positively associated with higher odds of having T2D.	9/9
8	Ahmad Esmaillzadeh, 2007 (71)	Iran	Cross-sectional	486 Tehrani female teachers selected by multistage cluster random sampling method, aged 40 – 60 years, with no prior history of chronic disease	Principal component analysis with orthogonal rotation	*healthy **Western ***Traditional	Adjusted odds ratios for abnormal glucose homeostasis and partial correlation coefficients with BMI adjustment for association with abnormal glucose blood levels	**Odds ratios:** *0.83 (0.49, 0.97) **1.11 (0.95, 1.46) ***1.19 (1.04, 1.59) **Correlation coefficients:** *r=0.13(p=0.11) **r=0.01(p=0.81) ***r=0.08(p=0.36)	Healthy dietary pattern was negatively associated with the odds of having abnormal glucose levels. All other results were statistically insignificant.	6/7
9	Nazanin Mosleh, 2016 (72)	Iran	Nested case-control study	178 T2D patients and 520 controls recruited from one district in Tehran, aged 32 – 56 years old with a mean of 43.6.	Principal component analysis	*Western **healthy ***Traditional	Odds ratios of having T2D	*1.10 (0.69–1.77) **0.93 (0.57–1.49) ***0.68 (0.41–1.11)	There was not enough evidence to conclude an association after adjustment for multiple variables including BMI	9/9

Study No.	First author and year	Region	Study design	Sample size and type	Method for identifying dietary patterns	Dietary patterns Studied	Analysis used	Results	Outcome	Study Quality
10	Tayebeh Doostvandi, 2016 (73)	Iran	Cohort, 3-year follow-up	802 adults recruited from one district in Tehran with no prior history of T2D, aged 28-50 years old with a mean age of 39	Principal component analysis with varimax rotation	*Western **Traditional ***healthy	Odds ratios of having insulin resistance	*1.58 (0.89-2.73) **1.58 (0.89-2.73) ***0.19 (0.10-0.36)	The healthy dietary pattern was associated with lower odds of having T2D. There was not enough evidence to conclude any other relationship.	8/9
11	L. Bekkouche, 2014 (74)	Algeria	Clinical trial	84 (11 men and 73 women) metabolic syndrome patients recruited from medical centres	Investigator defined	Mediterranean diet	A linear model analysis describing the changes before and after adopting the diet for fasting plasma glucose and HbA1c	**Fasting plasma glucose in mmol/l (+-SD)** Before:11.41(1.92) After: 7.26(1.85) p=<0.05 **HbA1c in % (+-SD)** Before: 89(17.63) After: 60.58(16.37) p=<0.05	There was a decrease in the fasting plasma glucose and HbA1c levels.	7/9
12	Massoud Amini, 2010 (75)	Iran	Cross-sectional	425 impaired glucose participants, 35 -55 years of age, first-degree relatives of T2D patients, recruited from the general population	Principal component analysis with orthogonal rotation	*Western **Prudent ***Vegetarian ****High-fat dairy *****Chicken and plant	Odds ratios of having high plasma glucose across tertile of major dietary patterns scores	*0.81(0.44-1.47) p=.49 **0.73(0.39-1.37) p=.34 ***2.26(1.25-4.06) p=.006 ****0.78(0.43-1.38) p=.39 *****0.89(0.51-1.58) p=.7	There were significantly higher glucose levels in the upper tertile of the vegetarian pattern compared with its lowest. There was not enough evidence to conclude other associations.	5/7

Table 3.3: Description of the dietary patterns identified by the systematic review

Dietary patterns	Names of the contained dietary patterns (study no.) [1]	Main components of the dietary pattern per each study	Individual studies' outcomes [2]	Main outcome [2]
Fast Food	- Fast Food/Western diet (3,4,5a) - Refined grains and desserts (5b) - Transitional Saudi (6) - Western (8) - Transitional Iranian (7) - Western (9) - Western (10) - Western (12)	(3) hamburgers, pizza, pies, carbonated beverages, butter, alcoholic beverages and sweets (4) legumes, eggs, fruit, sweets, fish, high-fat dairy products, French fries, potatoes, low-fat red meats, pizza, yellow vegetables (5a) white bread, French fries, added fat, fast-food sandwiches, mixed nuts, full-fat milk and milk products (5b) pasta, desserts, fried fish, pizza and pies, breakfast cereals and white bread (6) lamb, potatoes, pasta, whole fat cheese, chicken with skin, beef, cake and cookies, white bread, egg, oil, labneh, rice, full-fat yoghurt, chicken without skin, meat organ and full-fat milk (7) vegetables other than green leafy or yellow, fish, tea, low-fat dairy products, salt, organ meats, dried fruits, poultry, industrial fruit juices, eggs, sweets and desserts and legumes (8) processed meats, red meats, eggs, butter, high-fat dairy products, coffee, fruit juices, potatoes, French fries, refined grains, pizza, snacks, mayonnaise, sweets and desserts, hydrogenated fats, vegetable oils and soft drinks (9) fast food, salty snacks, soft drinks, cakes and cookies, fruit juice, vegetable oils, fish, refined grains, eggs and red meat (10) fast food, salty snacks, mayonnaise, soft drinks, high-fat dairy, hydrogenated oils, confectioneries and organ meats (12) sweets, butter, soda, mayonnaise, sugar, cookies, tail, hydrogenated fat, eggs, macaroni, liver and organic meat, coconut, mutton	(3) +ve (4) NS (5a,5b) +ve (6) +ve (7) +ve (8) NS (9) NS (10) NS	+ve

Dietary patterns	Names of the contained dietary patterns (study no.) [1]	Main components of the dietary pattern per each study	Individual studies' outcomes [2]	Main outcome [2]
Traditional	- Mediterranean (1) - Low-carbohydrate (2) - DASH (1) - Traditional Lebanese (3,5) - Traditional Saudi (6) - Traditional Iranian (7) - Traditional Iranian (8) - Traditional Iranian (9) - Traditional Iranian (10) - Mediterranean (11)	(3) full-fat dairy products, olives, fruits, legumes, grains, eggs, vegetable oil, nuts and dried fruits, traditional sweets and vegetables (5) olives and olive oil, fruits, vegetables, low-fat milk and milk products, traditional dishes, whole wheat bread and Arabic sweets (6) brown bread, breakfast cereal, chickpeas, beans, peas, brown rice and lentils (7) animal and hydrogenated fats, natural fruit juices, dried fruits, garlic, dough and high-fat dairy products. (8) tea, legumes, potatoes, whole grains, refined grains, hydrogenated fats and broth (9) whole grains, legumes, eggs, red meat, confectionery and traditional sweets, tea and coffee (10) refined grains, potato, eggs, vegetables, whole grains, fish, poultry, hydrogenated oils confectioneries, red meats, tea and coffee and legumes	(1) -ve (2) -ve (3) NS (5) -ve (6) -ve (7) +ve (8) NS (9) NS (10) NS (11) –ve (12) NS	-ve
High protein	- High protein (3) - Meat and alcohol (5) - Chicken and plants (12)	(3) fish, chicken, meat, low-fat dairy products and breakfast cereals (5) fruits, eggs, alcohol, red meat, sweetened juices and carbonated beverages, chicken and un-fried fish (12) mayonnaise, chicken, green leafy vegetables, fruits rich in vitamin A such as cantaloupes and apricots, candy and tea	(3) NS (5) NS (12) NS	NS

Dietary patterns	Names of the contained dietary patterns (study no.) [1]	Main components of the dietary pattern per each study	Individual studies' outcomes [2]	Main outcome [2]
Healthy	- American Diabetic Association diet (1) - Dietary approaches to stop hypertension (DASH) diet (2) -Semi-health dietary pattern (4a) - Vegetable and poultry dietary pattern (4b) - Healthy pattern (6a) Desirable fat pattern (6b) - Healthy (7) - Healthy (8) - Healthy (9) - Healthy (10) - Prudent (12a) - Vegetarian (12b)	(1) vegetables, whole grains, fruits, non-fat dairy products, beans, lean meats, poultry and fish (14) (2) high intake of fruits, vegetables, legumes and nuts, low-fat dairy products, low-intake of high-fat dairy products and red meat (4a) refined grain, fruits, nuts, tea, low-fat red meats and olives (4b) fruits, fish, poultry, low-fat dairy products, green and leafy vegetables, tomato, yellow vegetables, olive and other vegetables (6a) green leafy veg, cucumber, molokhia, tomatoes, okra, carrots, orange grapefruit, parsley, zucchini, pear and cabbages (6b) pistachio, fish, low-fat milk and milk products, almonds, olive oil, walnuts and cashew (7) vegetables, non-hydrogenated vegetable oils, fish, fruits, nuts and seeds, tomatoes, cruciferous vegetables, mayonnaise, condiments, low-fat dairy products and natural fruit juices (8) fish, poultry, low-fat dairy products, tea, fruit, fruit juices, cruciferous vegetables, yellow vegetables, tomatoes, green leafy vegetable, other vegetables, legumes, potatoes and whole grain (9) vegetables and vegetable oil, fruits, fish, nuts, milk and dairy products, poultry and legumes (10) salty snacks, vegetables, fruits, fish, poultry, fat diary (high and low), vegetable oils, nuts and seeds and legumes (12a) vegetable oil, liver and organic meat, coconut, juice, peas, barley, fish, dry fruits, nuts and honey (12b) sugar, cookies, legumes, potato, peas, low-fat milk, vegetables, fruit	(1) -ve (2) NS (4a, 4b) NS (6a,6b) -ve (7) NS (8) -ve (9) NS (10) –ve (12a) NS (12b) +ve	-ve

Dietary patterns	Names of the contained dietary patterns (study no.) [1]	Main components of the dietary pattern per each study	Individual studies' outcomes [2]	Main outcome [2]
Fruits predominate	- Miscellaneous pattern (6a) - Snacks pattern (6b) - High-fat dairy (12)	(6a) low-fat cheese, apple, kiwi, cinnamon and olives (6b) dates, canned fruit, apricots and melons (12) high-fat milk, high-fat yoghurt, fruits	(6a) NS (6b) NS (12) NS	NS

[1]For more details about each study, please see table 2.[2]+ve: have a higher association with T2D or its abnormal biometrics, -ve: have a lower association with T2D or its abnormal biometrics, NS: non-significant results to conclude a relationship

3.4 Discussion

The main aim of this systematic review was to summarise the current evidence for the relationship between T2D and dietary patterns in MENA regions. The extensive electronic database search for studies to be included in this systematic review yielded a wide range of study types that explored many different dietary patterns with some overlapping. The oldest study identified was only published ten years ago, possibly because it is only recently that there has been an interest in exploring the relationship between dietary patterns and diabetes, rather than individual foods or nutrients.

3.4.1 Dietary patterns across different regions and studies

Although there was no unified method in defining the dietary patterns in the studies, there was a high similarity in defining the components of the overlapping dietary patterns such as "healthy" and "Fast Food/ Western" dietary patterns. This similarity may be because food culture is relatively similar between the countries of the MENA region. Furthermore, due to the relative proximity in time between the studies, there would be minimal to no effect from changes over time in food culture, including defining food components for each dietary pattern among individual countries.

The high similarity in main features between many of the dietary patterns has made it possible to group them into the three main groups in Table 3.3. The similarity in features of those dietary patterns among the MENA countries may be due to both similarity in traditional cultures and the impact of globalisation in those countries. Nevertheless, there was a difference in the Traditional dietary patterns between some of the countries. While the main components of the Traditional diet, such as grains and vegetables, were similar in Iran and Lebanon, the Saudi Traditional dietary pattern included breakfast cereal among its components according to one study (69). Including breakfast cereal as a component of the Saudi Traditional dietary pattern may appear to be controversial. However, in this case, it can be explained by how dietary pattern was identified using factor analysis, with subsequently chosen names for the dietary pattern based on their main components.

3.4.2 Dietary patterns associated with glycaemia or T2D diagnosis

The two clinical trials included in this systematic review focused mainly on the Mediterranean diet, and one of the studies examined both the Traditional Mediterranean diet and a low-carbohydrate Mediterranean diet (64). Both were protective against T2D but the low carbohydrate diet was more protective. This finding is supported by the accumulating evidence for the benefits of low carbohydrate diets in weight loss and better control of T2D (76).

Otherwise, among the grouped dietary patterns, the Fast Food dietary pattern was found to be positively associated with T2D or abnormal glucose and HbA1c blood tests after controlling for multiple possible confounding factors in the studies that included this dietary pattern. A possible explanation for this association is that Fast Food dietary patterns combined foods that are high in fat and carbohydrates and glycemic loads such as processed meats and carbonated beverages. The Traditional and healthy dietary patterns had a protective effect against T2D, possibly because their food components such as vegetables and fish had higher fibre and protein content, and lower glycaemic load in comparison with the Fast Food dietary pattern food components (5).

3.4.3 Strengths and weaknesses of this review

This systematic review is the first to be done on the relationship between dietary patterns and T2D in the MENA region. It has several strengths including the use of three different search engines to find the relevant studies and the wide range of study types included. However, a possible limitation of this systematic review as an exhaustive review of all relevant studies is the limitation of initial searching via only electronic databases and the limitation of inclusion of only English language papers. A further limitation due to the heterogeneity of included studies is the inability to pool the data for meta-analysis due to the diversity of study types and populations included, as well as the variation in diet and outcome measures used across the studies.

3.4 Conclusion

Although dietary patterns have become increasingly used in dietary guidelines for patients with diabetes, only a few studies have explored diet as dietary patterns in the MENA region, including countries with a high prevalence of T2D such as Saudi Arabia. These studies do suggest that there is a relationship between dietary patterns and both the risk of developing T2D and between diet and glycaemic control. Further research is needed to explore the relationship between dietary patterns and T2D in specific populations to take account of the cultural specificity of dietary patterns. Such evidence could potentially inform the development of future evidence-based national dietary guidelines for both better management and prevention of diabetes.

3.5 Systematic review chapter summary

This systematic review aimed to summarise evidence that links dietary patterns to T2D or its parameters such as HbA1c. To find a sufficient number of studies, the geographic focus of this systematic review was expanded to include the countries of the Middle East and North Africa (MENA) that have some similarities in their food cultures to Saudi Arabia.

In total 12 studies were identified in which the most common dietary patterns were labelled Traditional, Fast Food/Western and healthy (64,65,74,75,66–73). Overall, the Fast Food/Western dietary patterns were found to be positively associated with T2D while the Traditional and healthy dietary patterns were found to be negatively associated with T2D.

There was only one study that examined the association between dietary patterns and T2D in Saudi Arabia and it recruited only diabetic patients from a hospital setting (69). Thus, there is still a large research gap in the association between dietary patterns and T2D in Saudi Arabia suggesting that further research is needed in this area.

Chapter 4: Methods

4.1. Introduction

This chapter describes the methodology of two cross-sectional studies that addressed the question “What are the dietary patterns and dietary predictors of T2D in a Saudi population?” The first one is the Saudi Health Interview Survey (SHIS) (2013) (46) from which the survey data were obtained for secondary data analysis. The second one is primary data from a cross-sectional study that were collected using a more detailed FFQ used in a previous study for the Saudi population (77) and which has been modified from the European Prospective Investigation into Cancer (EPIC) FFQ (78). Methods for the data collection and data analysis will be discussed for both studies in this chapter.

This chapter includes the research objectives, study design, inclusion criteria for this research, recruitment strategy, data collection methods including timetable and locations, sample size calculations, data collection instruments, the analysis plan and ethical approval including the patient consent process.

4.2. Main research objectives

1. To identify common dietary patterns among the Saudi population.

2. To determine what dietary patterns are associated with T2D, BMI level and HbA1c level in the general Saudi population, in individuals with undiagnosed T2D and individuals with diagnosed T2D.

4.3 Saudi Health Interview Survey data collection methods

The main objectives of this section are to describe the methods used for the SHIS data collection and how the secondary data were prepared for analysis. However, to better understand the rationale behind the SHIS methods, this section will also contain some background information about the SHIS.

4.3.1 The background of the SHIS

In 2013, the MOH of Saudi Arabia in collaboration with the IHME conducted a national health interview survey to assess chronic disease states and risk factors linked to them, including diets and behaviours in Saudi Arabia (46). As indicated by its name, the Saudi national health interview survey was an interview survey, carried out by trained individuals using a structured questionnaire that aimed to collect data from individuals aged 15 or older in Saudi Arabia. The survey consisted of four main parts: a household roster, a questionnaire, physical measurements, and a lab-based biomedical examination. The household roster part helped to obtain information related to the demographics and socioeconomic status of participants. The questionnaire had information regarding chronic disease and diet. In addition to the physical measurement of height and weight that allowed calculation of the BMI of participants, the lab-based biomedical examination included random blood glucose and HbA1c level.

4.3.2 The SHIS survey objectives

The main objective of this survey was to help the Ministry of Health of Saudi Arabia to develop and implement its control and prevention plan for various chronic conditions. This would be done by collecting demographics, health and behavioural data including risk factors on those chronic conditions (46). In addition to helping in the development of control and prevention plans, the data collected by the survey has also been used to understand the predictors of behaviour such as diets that are associated with chronic health conditions including T2D (51,58,79–81).

4.3.3 The SHIS sample

The survey had a sample size of 10,821 participants. HbA1c test results were missing for 6,360 of the participants. However, 10,533 answered the question relating to having or not having diabetes and which type.

As the SHIS was a national survey, all of the 13 provinces were included in this survey (55). Sub-regions within each province were selected randomly using a probability-proportional-to-size approach (55). Households were also selected randomly and at least 3 attempts were made to interview a resident from the selected households before changing the selection (55). This approach was undertaken to ensure that the SHIS would be representative of the Saudi population.

4.3.4 The SHIS survey data collection

The data collection process was carried out by trained individuals while being overseen by the MOH of Saudi Arabia. The trained data collectors would interview the participant to acquire the required information (46).

Both data collectors and their supervisors underwent training from experts in survey collection from both the Saudi MOH and an external organisation (IHME). The training involved introducing the survey contents, protocols for data collection and the appropriate methods for physical measurements. Training sessions involved both software and in-class practical training. A pilot study was also done to familiarise the data collector with the field process. The survey was modified according to various problems encountered within the pilot study (46).

Having the data collectors and their supervisors undergoing the same training process can help to ensure consistent quality for the data collected while having a pilot study can help in minimising the errors that can occur from the individual judgment of the data collectors in various possible situations.

4.3.5 The unique opportunity presented by the SHIS

The 2013 SHIS represents a unique opportunity to study T2D in relation to diet in a representative adult Saudi population from the perspective of both dietary patterns and single dietary items. Only a few studies have examined the relationship between diet and T2D in Saudi Arabia and these have been done on a relatively small sample in comparison with the sample of the SHIS data (9,19). This study explored the relationship between diet and T2D in Saudi Arabia using a large sample from the SHIS data, considering both single dietary factors and dietary patterns.

4.3.6 The survey questions about diet

The dietary information collected in the SHIS questionnaire was limited to the following specific 18 food items: fruits, juices and smoothies, vegetables, dark meat fish (like salmon), and non-dark meat fish, red meat, poultry, shrimp, processed meat, processed food, eggs, nuts, milk, laban, yoghurt, labneh, cheese and carbonated drinks (46). All these items had questions relating to their weekly and daily frequencies of consumption.

4.3.7 The survey questions about diabetes

The survey questions related to diabetes included a question about the presence or absence of a diagnosis of diabetes, type of diabetes, the age of diagnosis and the use and type of insulin and other diabetic medications.

In addition to the question about diabetes, a blood sample was acquired for laboratory analysis. These analyses included tests for random blood glucose and HbA1c levels. While blood glucose would only indicate the blood glucose level within the past few hours, HbA1c can indicate the blood glucose level for the previous 2-3 months (7).

A complete detailed list of variables acquired from SHIS for secondary data analysis in this chapter is included in Appendix 1.

4.3 Primary data collection methods

4.4.1 Study design

The cross-sectional study design has been used to further address the research questions by collecting more detailed dietary data. The data for this research were collected from health centres in Medina, Saudi Arabia, using an interview survey. Also, blood samples were obtained from participants participating in the survey for HbA1c testing.

In a cross-sectional study design, data are collected at only one point which will eliminate the need to follow-up with the participants after filling in the interview survey allowing for a larger sample size during a shorter period in comparison with other observational studies (82). However, the lack of the sequencing of events in the cross-sectional study design will make it difficult to distinguish between the diets of patients with T2D before and after diagnosis. Nevertheless, we were able to explore which dietary patterns were associated with better control of T2D. Furthermore, conducting the HbA1c blood tests allowed us to compare dietary patterns among individuals with no T2D diagnosis based on the levels of HbA1c. This also allowed us to inform the undiagnosed diabetic and pre-diabetics about the need to seek medical advice, which was a potential benefit for participating in this study.

4.4.2 Interview surveys

The benefits of using an interview survey:

Data were collected using an interview survey (46). The benefits of an interview survey include a higher response rate in comparison with self-administrated questionnaires and the ability to include participants with no to a low level of education. A higher response rate will ensure less bias and more generalisability of the result to the external population as individuals who would respond to the self-administrated questionnaire are usually more educated, more interested in health or better off than non-respondents and therefore not representative of the population (83). Besides, it is easier to acquire a blood sample from participants at the time of the interview, rather than contacting them after filling out the questionnaires to arrange an appointment for blood sample collection.

Interview surveys represent the least cognitively demanding method for administrating a questionnaire (83). Answering a question requires four cognitively demanding steps: understanding the question, recalling the needed information, assessment of the relationship between the recalled information and the question, and communicating the answer. Interview questionnaires require the respondent only to have basic verbal and listening skills with no reading skills involved (83). Interview surveys require the respondent only to have basic verbal and listening skills. Also, the interviewer can clarify the ambiguity of questions, maintain motivation with long questionnaires, aid in recall for events and behaviours, prompt for response and, by being friendly, ensure a higher response rate. Also, interview surveys don't require access to telephone contacts as in telephone surveys or a computer and the internet as in electronic surveys (83).

The weaknesses of using an interview survey:

A main weakness of the interview survey is the possibility of inducing social desirability bias. In comparison with other modes of questionnaire administration, the respondents in an interview survey have been shown to give more positively socially desirable responses resulting in over-reporting of desirable behaviours while under-reporting those which are undesirable, such as over-reporting eating healthy foods while under-reporting eating unhealthy foods (83). However, as mentioned previously in the methods chapter, this can be limited by ensuring the participants that the data collected will be anonymised and that the researchers are more interested in what they ate rather than what they should eat. Furthermore, assuming over-reporting is the same for all participants, differences between groups in the diet will still be detected.

4.4.3 Inclusion and exclusion criteria

Data were collected from an opportunistic sample of adults aged 18 or older attending health centres in Medina, Saudi Arabia. Data were also collected from both patients who have a diagnosis of T2D and those without a T2D diagnosis. Type 1 diabetic patients were excluded from the survey as their diet is likely to be different from both non-diabetic patients and those with T2D.

4.4.4 Data collection sources

To seek more generalisability of the results and to collect the largest possible sample, the data were collected from five primary health centres in Medina, Saudi Arabia. Participants were interviewed while they were in the waiting area and physical measurements and blood samples were acquired in the examination room. Nurses were asked to assist in the female section.

Although this study aimed to collect survey data from both diabetic and non-diabetic patients, the primary health centres with the highest number of registered diabetic patients were targeted for data collection. Based on the information obtained from the administration of health affairs in Medina, the top five primary health centres with the highest registered number of T2D patients are Alaziziah, Wa'irah, Quba'a, Said Alshuhda'a and Aldia'itha.

About the city of Medina:

Medina is one of the main cities in Saudi Arabia with a population of about two million (84). Its holiness for Muslims attracts people from different locations in Saudi Arabia to live in it. This would achieve more generalisability of the results across a wider Saudi population.

Primary health centres selected for data collection:

Table 4.1 shows the names of the primary health centres which were used for primary data collection. It also contains information about the registered number of diabetic patients obtained from the Administration of Health Affairs in Medina, Saudi Arabia.

Table 4.1: Names of health centres selected for primary data collection and numbers of registered diabetic patients for each centre

Health centre name	No. of registered diabetic patients[1]
Alaziziah	1352
Wa'irah	866
Quba'a	749
Said Alshuhda'a	745
Aldia'itha	677

[1]These figures have been obtained from the Administration of Health Affairs in Medina, Saudi Arabia.

4.4.5 Sample size needed for primary data collection

The sample size needed for this research should be large enough to identify significant differences in dietary patterns between those with and without diabetes. Based on previous studies included in the systematic review in Chapter 3, it was possible to identify significant differences in dietary patterns between groups with 80-100 respondents (74). This suggests that having 100 respondents providing detailed dietary information in each group to be compared would be sufficient to identify differences in the diet if they are present.

4.4.6 Data collection instruments

The survey instrument for primary data collection was designed by adapting questions regarding demographics such as age and income levels and questions regarding health conditions such as having a family history of T2D from the SHIS Questionnaire (46) (Appendix

1). Also, dietary data were collected using a modified version of the European Prospective Investigation into Cancer and Nutrition (EPIC) FFQ (85) that has been used in a previous study also examining the genetic factor of T2D within the Saudi population (77) (Appendix 2). The EPIC FFQ was modified by removing some of the questions that do not relate to the Saudi diet such as eating pork or drinking alcohol and by adding questions specific to the Saudi diet such as eating date fruit or drinking Arabic coffee. The survey was also translated into Arabic. The survey itself was available in both Arabic and English for faster administration of the questionnaire since all questions were asked in Arabic and data entry and analysis was in the English language. It also allowed the questionnaire to be administered to non-Arabic speakers, although they are rare in Saudi Arabia, and the ability to be reviewed if necessary, by non-Arabic speakers.

The questionnaire consisted of four sections: interview information, sociodemographic, health status, FFQ and lastly physical and laboratory information. Table 4.2 shows a summary of the variables and items included in each part.

Table 4.2: Summary of the variables contained in the data collection instrument

Main item	Variable measured or recorded	Source of the instrument used
	Section 1	
Interview information	Interviewer name or ID, date, time, confirmation of consent, confirmation of diabetic status (to exclude type 1 diabetics), participant name and participant contact phone number	SHIS
	Section 2	
Sociodemographic information	Sex, age, marital status, level of education, and an estimate of household income in Saudi riyals	SHIS
	Section 3	
Health questionnaire	Smoking status, physical activity, diabetes medications, past medical history of chronic diseases, family history of diabetes, if a change to diet after diabetic diagnosis, nature of those changes	SHIS
Food frequency questionnaire	Main categories: meat and fish, bread and grains, sandwiches and burgers, dairy products, sweets and snacking, drinks, fruits and vegetables	Modified EPIC FFQ
	Section 4	
Physical and laboratory information	Height, weight and HbA1c level	Directly measured

The interview information section

The interview information questions were on the cover page of the survey, which had the name of the survey and asked for the name of the interviewer and interviewee, date and time, confirmation of whether the individual had T2D (and did not have type 1 diabetes).

The sociodemographic section

The sociodemographic part collected information related to the demographics and socioeconomic status of participants. Participants were asked about sex, age, and marital status, level of education and estimates of income. Participants were also asked to estimate the level of income for their household as a whole to be used as an indicator for the participants' socioeconomic status.

The health section recorded responses about smoking status, physical activity and past medical history of diabetes and other chronic conditions. By knowing the presence or absence of a T2D diagnosis, it was possible to identify the undiagnosed diabetic group using the HbA1c. Also, past medical history of other chronic diseases was recorded as people may change their diet due to having a diagnosis of chronic disease (as well as due to a diagnosis of T2D, obesity or overweight.

The sociodemographic part of the questionnaire was adapted from the SHIS questionnaire which was specifically designed for use in Saudi Arabia. Furthermore, by collecting the same sociodemographic information as the SHIS, it was possible to compare the results of both the primary data and the secondary data acquired from the SHIS.

The FFQ section

The FFQ is based on the EPIC questionnaire that has been adapted to include Saudi specific foods (85). The questionnaire contains 125 questions about different food items categorised in eight subgroups of food types. These subgroups include meat and fish, bread and grains, sandwiches and burgers, dairy products, sweets and snacks, drinks, fruit and vegetables. Each of these food type subgroups contains questions for about 8-23 food items as seen in Table 4.3. For each of the food items, the frequency of consumption was assessed using a scale ranging between "never" to "six or more times per day". A score was given for each answer that indicates the estimated frequency of consumption per day for each food item. Mean frequencies of consumption per day were used to compare food items during analysis.

Table 4.3: Food categories with food items included in the food frequency questionnaire

Food category	Food items included
Meat and fish	Lamb meat, grilled meat, meat kebab, chicken kabsa (meat and rice dish), fried chicken, grilled chicken, chicken kebab, camel meat, cow meat, sausage, shawarma dish, liver dish, fried fish, grilled fish, tuna and canned fish and shrimp
Bread and grains	white rice, biryani rice, white bread, brown bread, asidah (semolina-based dish), pizza (one piece), macaroni, breakfast cereals, baked items, mashed potato, baked potato, fried potato and ma'sop
Sandwiches and burgers	Liver sandwich, egg sandwich, meat sandwich, chicken sandwich, falafel sandwich, meat burger, chicken burger and shawarma
Dairy Products	Cream cheese, white cheese, low-fat cheese, full-fat cheese, low-fat yoghurt, fat-free yoghurt, full-fat cream, low-fat cream, fat-free cream, full-fat labneh, low-fat labneh, fat-free labneh, whole milk (cup), low-fat milk (cup), fat-free milk (cup), full-fat laban, low-fat laban, fat-free laban, caramel, egg (one egg), mayo (one spoon), butter (teaspoon) and margarine
Sweets and snacks	Ice-cream, chocolate, sugar (teaspoon) added to tea or coffee, chips, nuts such as peanuts, salted biscuit, sweet biscuit, cake, pastry eg croissant, soup (bowl), sauces (such as ranch or cheese), ketchup, pickles and jam (spoon)
Drinks	Red tea (cup), green tea (cup), Arabic coffee, express coffee as cappuccino (cup), decaf coffee, cacaoa, sodas, diet sodas, no-calories sodas, juices and smoothies with no sugar added, fruit drinks, condensed fruit drinks (such as Femto)
Fruits	Date, apple, pear, mango, grape, orange or margarine, pineapple, cantaloupe, banana, watermelon, peaches, strawberries, plum, apricot, berries, avocado, kiwi, canned fruits such as pineapple, and dried fruits
Vegetables	Green salad, cucumber, pumpkin, spinach, broccoli, cabbage, peas, beans, courgettes, cauliflower, shallots, onions, garlic, mushrooms, bell peppers, carrots, lettuce, tomato, corn, beets and lentils

The physical and laboratory information section

The last part of the survey was about physical measurements and laboratory-based biomedical tests. The physical measurements included height and weight (measured in the clinic) to allow calculation of BMI. Furthermore, the lab-based biomedical examination included recording HbA1c level which helped to identify both undiagnosed diabetic cases and uncontrolled type 2 diabetics.

To avoid unnecessary invasive procedures if the HbA1c test had already been carried out within the last 3 months for any of the participants, it was acquired from their medical files with their consent. If a new test was needed, primary health centres were asked first if they could perform the HbA1c test to ensure more standardisation and to lessen the costs. If that was not possible, blood samples were collected from the fingertips of the participant using disposable finger sticks rather than needles. After that, an HbA1c test was done for instant results using a portable HbA1c test named A1cNow+© (86). Previous studies have shown that this portable HbA1c test is highly accurate and consistent with standard laboratory HbA1c tests with no more than 0.09% variation in results (86). If any participants were found to have an HbA1c level more than 6% and no T2D diagnosis, another test was performed using the portable HbA1c test to confirm the results before asking the participant to seek medical attention regarding their blood glucose level.

4.4.7 Rationale for using a food frequency questionnaire over other methods

Many methods can be used to assess diet such as food diaries, weighed food records, estimated food records, 24-hour recall and food frequency questionnaires (FFQ).

Weighed food records

Weighed food records is a method of dietary assessment using food diaries. Its greatest strength is that it provides very precise information for portion sizes (87). However, this method of dietary assessment also has a very high burden on respondents which can make it more difficult to recruit a large sample of participants (87). Furthermore, dietary pattern assessment is more concerned with the types of food rather than their portion sizes (88).

Estimated food records

Estimated food records is also a dietary assessment method that uses food diaries. Since it depends on participants' estimation of portion sizes rather than actual measurement, it carries less burden for participants in comparison with weighed food records (87). However, the estimation also makes it less precise in terms of its information on portion sizes.

24-hour recall

The 24-hour recall is a method of dietary assessment that is more concerned with what participants consumed during the last 24 hours. It has a very low burden for respondents, can be used for large-scale survey and can be carried out through telephone calls (88). However, this method can only measure what participants ate in the last 24 hours; it may, therefore, be more difficult to link its results to chronic diseases that require years to develop such as T2D, if an individual's diet has significantly changed over time.

Food Frequency Questionnaire (FFQ)

Food frequency questionnaires are questionnaires that measure the frequency of consumption (e.g. daily, weekly, and monthly) for a list that has multiple food items, which can be in the hundreds. It can be self-administered or administered by an interview or telephone (87,89).

This research aimed to assess the relationship between diet and chronic disease that requires a long time to develop. Therefore, FFQ was considered to be a more suitable method to evaluate long-term habitual dietary intake of participants. Furthermore, food frequency questionnaires are more suitable for administration to a larger sample of participants (100 or more) (87).

Nevertheless, unless modified to be a semi-quantitative questionnaire by adding questions about the estimated portion size, food frequency questionnaires lack information about actual food quantities. A food frequency questionnaire will also have a lower burden for respondents in comparison with other methods of dietary assessment such as food records (87). Table 4.4 shows a comparison of the strengths and weaknesses of different methods of dietary assessments.

4.5 Descriptive statistical analysis

Unless specified otherwise, all statistical analysis was done for both the primary data and the secondary data acquired from the SHIS in the same manner.

4.5.1 Data preparation

The secondary data of the SHIS were obtained from the Ministry of Health of Saudi Arabia as an Excel file. The primary data were also entered into an Excel file and rechecked for accuracy. Furthermore, for each outlier detected within the data, the original questionnaire was pulled out to recheck the accuracy of the entered value. Both data sets were imported to SPSS 23 (IBM Corp, 2015) for all of the analysis. Secondary variables such as BMI, HbA1c diagnosis group and T2D diagnosis groups were generated using SPSS computing and recoding functions. Any extreme outliers were excluded from all continuous variables before analysis. Lower extreme outliers were identified using the formula Q1-(3xIQR) while higher extreme outliers were identified using the formula Q3+(3xIQR) (90). Examples of these extreme outliers includes, for example, having a bodyweight over 300 KG or frequency of consumption of 50/day for a food item. Data for dietary items were computed into new variables showing the frequency of serving per day for each of the dietary items.

4.5.2 Type two diabetes case definition

Both those who reported a diagnosis of T2D and those who have a diabetic level of HbA1c but no diagnosis were identified within the data and have been included in the analysis as separate groups from those who have no diabetes. The main expected difference between these two groups (diagnosed and undiagnosed T2D) is that those who already have a diagnosis might be expected to have changed their diet in response to dietary advice at the time of diagnosis or as an element of diabetes management.

Undiagnosed T2D cases were defined as those having an HbA1c of 48 mmol/mol (6.5%) or over but not reporting a diagnosis of diabetes. Although a value of less than 6.5% of HbA1c doesn't exclude diabetes, a value of 6.5% or over is diagnostic of diabetes while an HbA1c value of 6 to 6.49 is defined as pre-diabetes (7). Participants who reported a diagnosis of type 1 diabetes or those who did not respond or know their diabetes type were excluded from the analysis to avoid any misleading results while comparing between diagnosed T2D, undiagnosed T2D and non-diabetic cases.

4.5.3 Demographic and health characteristics analysis

Age and sex have been displayed using bar charts with error bars (standard error of the mean (SEM)) for both the primary and secondary data study samples. Further demographic and health characteristics such as BMI, HbA1c levels, T2D diagnosis, education level, income estimates, physical activity, history of chronic disease other than T2D, smoking status, and family history of T2D were displayed using bar charts with error bars (SEM) while also being stratified by age group and sex.

To explore and illustrate the distribution of participants in the survey sample by age, participants were grouped into the age groups 18-29, 30-39, 40-49, 50-59, 60-69 and 70 or more years. The secondary data analysis had an additional category of less than 18 since they included participants who were 15 years or older.

4.5.4 Single dietary items analysis

Both primary and secondary data had a summarising table that displayed the important demographic and health characteristics of each study sample. Continuous variables were presented as means, standard deviations and ranges while categorical variables were presented as ratios.

Secondary data:

Individual dietary factors for the secondary data included 18 food items: fruits, juices and smoothies, vegetables, dark meat fish (like salmon), and non-dark meat fish, red meat, poultry, shrimp, processed meat, processed food, eggs, nuts, milk, laban, yoghurt, labneh, cheese and carbonated drinks (46). For comparison and in order to understand the dietary difference within the Saudi population, descriptive analysis for these items was done using bar charts with error bars (SD) displaying the mean daily frequency of consumption while also being stratified by the demographic and health characteristics mentioned in the previous section.

Primary data:

The same previously mentioned descriptive analysis was also done for the single dietary items in the primary data. However, before this analysis was done, the 125 single items from the primary data were grouped into 28 items. The grouping was done based on the similarities of nutritional profiles and culinary practices of the grouped items and also by taking into account the process of factor analysis. The grouping and the resulting food items are described in more detail in Section 5.4.1.

Analysis excluding those with diagnosed diabetes:

On the assumption that those with a diagnosis of diabetes may have changed their diet in response to their HbA1c levels (reverse causality), the analysis was also conducted on a sample excluding those with a diagnosis of diabetes (which included both undiagnosed diabetes and pre-diabetic hyperglycaemic participants).

4.6 Factor analysis

4.6.1 Principle Component Analysis as the method of data extraction:

Principle Component Analysis (PCA) is a multivariate analysis that was first introduced in 1901 (91). However, due to its mathematically complicated nature, it has only been widely used in recent years owing to the statistical processing power of modern computers (91).

PCA is a default choice out of the extraction methods for factor analysis in statistical packages such as SPSS. However, unlike the other method of data extractions for factor analysis, such as maximum likelihood or principal axis factor, PCA is a method of data reduction that aims to extract meaningful interpretations from complex and less clear data sets while not assuming the presence of a latent variable (91–93). In other words, the methods of data extraction for factor analysis other than PCA have the purpose of identifying the latent variable that cannot be measured directly. These variable effects can be seen from the participants' responses and therefore can be measured through the variables' covariance. Alternatively, PCA can be used as it can provide a simpler structure for complex data sets by employing a data reduction method which does not depend on identifying the presence of latent or unknown variables (93). This makes PCA the more suitable extraction method to derive dietary patterns from observed and recorded food frequency data.

However, regardless of the method of data extraction used, for an accurate interpretation of the resulting structure, the variables within the factor analysis structure should be, to some extent, related to each other (94). Bartlett's test of sphericity is a hypothesis test that detects the probability of the variables being unrelated to each other (94).

4.6.2 Exploratory and confirmatory factor analysis

To derive the dietary patterns, exploratory factor analysis is used in which multiple rotations, removal of items that have very low to no loading and a different number of factor solutions are utilised to reach the best structure (88). The best structure is described as having the minimal number of cross-item loading between the resulting patterns and each pattern should also have several strong-item loadings (>0.3) (93).

Upon reaching the best structure for dietary patterns with the appropriate solution for the PCA, confirmatory factor analysis can be used to make sure the result is both valid and replicable. This can be done by randomly selecting and splitting the sample into halves to find out if the same dietary patterns result from using the same solution (95).

4.6.3 The adequacy of sample size for factor analysis

Studies were able to successfully draw factor analysis results from a wide range of sample sizes ranging from having a subject to item ratio of 10:1 to having a ratio of less than 2:1 (93). While some of the studies suggest different fixed ratios of the subject to the item to perform a successful analysis, many other studies have suggested that the adequate sample size is highly dependent on the nature of the data (96,97).

To make sure that the sample size is adequate for the intended number of variables within the PCA, Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy can be done (98). This test can measure the adequacy for a sample for each variable by measuring the proportion of variance among variables. A KMO value above 0.6 indicates that the sample is adequate for the analysis (98).

4.6.4 Rotations

Following the choice of methods for data extraction, the next step is usually choosing the rotation (99). Rotation does not increase or alter the amount of variance produced by the extraction method (99). However, the goal of rotations is to produce a more simplified and clearer data structure (93). There are mainly two categories of rotations which are orthogonal and oblique rotations (93,99).

Varimax, quartimax and equamax rotations are the common methods used for orthogonal rotations while the oblique methods include the direct oblimin and Promax (93,99). Oblique rotations assume a correlation between factors and therefore it is the preferred choice if such correlation exists at an acceptable level (above 0.32 for any of the factors) to allow the factors to correlate (93). If the correlation between the factors is weak, orthogonal rotation becomes the preferred method to produce a more accurate structure that does not allow the factors to correlate with each other (93).

Varimax rotation is the most commonly used rotation among the orthogonal rotations (93,99). Varimax aims to produce the simplest possible solution by ensuring that each factor would have a small number of large loadings and a large number of very small loadings (99). This can simplify the interpretation of factors because each factor would be represented by a smaller number of variables (99).

4.6.5 Variables to be included in the factor analysis

To derive the dietary patterns among the Saudi population, all the 18 food items from the secondary data were included for the secondary data factor analysis. As for the primary data, the FFQ contained 125 food items. However, analyses based on that number of items could make it more difficult to produce interpretable patterns. Therefore, similar dietary items have been grouped based on their nutritional profile or culinary methods such as grouping low-fat dairy foods together and grouping fried fish with fried chicken resulting in a total of 28 food groups (Table 4.4). Foods that did not fit with any other food item were classified individually.

Table 4.4: Grouped dietary items with their nutritional profile

	Grouped items	Ungrouped items	Nutritional profile in g per 100g (100ml for drinks) [1]			Calories/100g (/100ml for drinks)[1]
			Protein	Fat	Carbohydrates	
1	Red meat	Lamb meat	14.97	23.54	0	272
		Cow meat	17.32	24.05	0	286
		Camel meat	22	1	0	97
		Meat kebab	23	31	0	371
		Grilled meat	5.88	3.53	10.98	99
		Liver dish	20.38	5.02	1.78	134
2	Chicken	Chicken	18.14	5.04	1.14	122
		Grilled chicken	10.21	9.51	24.30	224
		Chicken Kebab	12	3	2	83
		Shaorma dish	6.67	2.35	17.65	118
3	Fried chicken and fish	Fried chicken	10.96	36.61	22.54	463
		Fried Fish	13.49	10.79	16.89	219
4	Seafood	Grilled fish	20.08	1.70	0	96
		Tuna and canned fish	23.33	4.9	0	137
		Shrimp	10.62	5.31	4.42	108
5	Processed meat	Sausage	10.71	26.79	7.14	313
		Meat burger	16.81	20.35	0	250
		Chicken burger	21.34	6.25	0.89	145

	Grouped items	Ungrouped items	Nutritional profile per 100g (100ml for drinks) [1]			Calories/100g (/100ml for drinks)[1]
			Protein	Fat	Carbohydrates	
6	Rice and Macaroni	White rice	4.2	0.44	44.5	199
		Biryani rice	4	4.5	30	177
		Macaroni	13.04	1.51	74.67	364
7	White bread	White bread	8.85	3.33	49.42	263
8	Brown bread	Brown bread	8.45	2.82	53.52	273
9	Baked items	Pizza (one piece)	11.73	12.56	29.93	280
		Other baked items	-	-	-	-
		Pastry such as croissant	8.2	21	45.8	405
10	Non-fried potato	Mashed potato	7.41	0.37	74.07	329
		Baked potato	7.14	12.5	75	441
11	Fried potato	Fried potato	2.38	3.57	21.43	127
12	Sugary breakfasts	Asidah	-	-	-	-
		Ma’sop	-	-	-	-
		Breakfast cereals	9.38	4.69	81.25	405

	Grouped items	Ungrouped items	Nutritional profile per 100g (100ml for drinks) [1]			Calories/100g (/100ml for drinks)[1]
			Protein	Fat	Carbohydrates	
13	Sandwiches	Falafel sandwich	7.93	4.41	27.75	182
		Liver sandwich	18	18	21	318
		Meat sandwich	10.71	9.82	26.34	237
		Chicken sandwich	12.16	7.43	29.73	234
		Shawarma Sandwich	21	7	24	243
		Egg sandwich	9.60	12.63	19.19	229
14	Full-fat dairy items	Whole milk	7.86	7.93	11.03	147
		Full-fat laban	3	3	4	55
		Yogurt	3.47	3.25	4.66	62
		Cream cheese	7.14	35.71	3.57	364
		White cheese	25	32	3.57	402
		Full fat labneh	1	6	2	66
		Full-fat cream	3	23	4	235

	Grouped items	Ungrouped items	Nutritional profile per 100g (100ml for drinks) [1]			Calories/100g (/100ml for drinks)[1]
			Protein	Fat	Carbohydrates	
15	Low and fat-free dairy items	Low-fat milk	8	4.8	12	123
		Low-fat laban	3	1	4	37
		Low-fat yoghurt	3.33	2.08	7.92	64
		Fat-free milk	3.33	0	4.58	32
		Fat-free laban	3	0	5	32
		Fat-free yoghurt	6	0	15	84
		Low-fat cheese	11.5	0.88	4.42	71
		Low-fat cream	8	2	12	98
		Low-fat labnah	3.39	0.85	4.66	40
		Fat-free cream	3	0	16	76
		Fat-free labnah	8	0	4	48
16	Margarine and butter (teaspoon)	Margarine	0	78.57	0	707
		Butter (teaspoon)	0.85	81.11	0.06	734
17	Egg	Egg (one egg)	12.56	9.51	0.72	139

	Grouped items	Ungrouped items	Nutritional profile per 100g (100ml for drinks) [1]			Calories/100g (/100ml for drinks)[1]
			Protein	Fat	Carbohydrates	
18	Confectionary and other sweets	Salted biscuit	8.11	9.46	67.57	388
		Sweet biscuit	7.2	21.5	62.7	473
		Cake	4.04	19.19	51.52	395
		Ice-cream	2.86	10	24.29	199
		Chocolate	9.52	40.48	47.62	593
		Caramel	4.6	8.1	77	399
19	Crisps	Crisps	3.57	32.14	53.57	518
20	Nuts	Nuts	21.43	46.43	25.00	604
21	Dried fruits and pickles	Canned fruits e.g. canned pineapple	1.09	0.02	28.11	117
		Dried fruits	2.5	0	65	270
		Pickles	0.33	0.2	2.26	12
22	Soup	Soup (bowl)	-	-	-	-
23	Sugar (added to coffee and tea)	Sugar (teaspoon) added to tea or coffee	0	0	99.77	399

	Grouped items	Ungrouped items	Nutritional profile per 100g (100ml for drinks) [1]			Calories/100g (/100ml for drinks)[1]
			Protein	Fat	Carbohydrates	
24	Sauces such as ketchup and mayo	Mayo (one spoon)	0	40	6.67	387
		Sauces (such as)	1.32	44.54	5.9	430
		Ketchup	1.04	0.10	27.40	115
		Jam (spoon)	0.37	0.07	68.86	278
25	Tea and coffee	Red tea (cup)	0	0	0	0
		Green tea (cup)	0.07	0	0	0
		Arabic coffee	0	0	0	0
		Express coffee as cappuccino (g)	0.30	0	0.17	2
		Decaf coffee (g)	0.12	00	0.43	2
26	Cold beverages	Cocoa (g)	3.17	3.39	10.34	85
		Carbonated drinks	0	0	65.70	263
		Caned fruit drinks	0	0	12.08	48
		Condensed fruit drinks	0	0	31	124
		Juices	-	-	-	-
		Carbonated sugar-free beverages	0	0	0	0

	Grouped items	Ungrouped items	Nutritional profile per 100g (100ml for drinks) [1]			Calories/100g (/100ml for drinks)[1]
			Protein	**Fat**	**Carbohydrates**	
27	Fruits	Date	0.43	0.04	17.99	74
		Pineapple	0.54	0.12	13.12	55
		Cantaloupe	0.84	0.19	8.16	37.
		Watermelon	0.61	0.15	7.55	34
		Apricot	1.40	0.39	11.12	54
		Apple	0.26	0.17	13.81	58
		Pear	0.36	0.14	15.23	64
		Mango	0.82	0.38	14.98	67
		Grape	0.81	0.47	13.93	63
		Orange or margarine	0.94	0.12	11.75	52
		Banana	1.09	0.33	22.84	98
		Peach	0.91	0.25	9.54	44
		Strawberry	0.67	0.30	7.68	36
		Plum	0.70	0.28	11.42	51
		Berries	0.74	0.33	14.49	64
		Avocado	2	14.66	8.53	174
		Kiwi	1.14	0.52	14.66	68

	Grouped items	Ungrouped items	Nutritional profile per 100g (100ml for drinks) [1]			Calories/100g (/100ml for drinks)[1]
			Protein	Fat	Carbohydrates	
28	Vegetables	Green salad	-	-	-	-
		Cucumber	0.65	0.11	3.63	18
		Spinach	2.86	0.39	3.63	29
		Broccoli	2.82	0.37	6.64	41
		Cabbage	1.28	0.10	5.80	29
		Peas	5.42	0.40	14.45	83
		Beans	1.83	0.22	6.97	37
		Courgette	1.21	0.32	3.11	20
		Cauliflower	1.92	0.28	4.97	30
		Shallots	2.5	0.1	16.8	78
		Onions	1.1	0.1	9.34	43
		Garlic	6.36	0.50	33.06	162
		Mushrooms	3.12	0.57	5.10	38
		Bell peppers	0.80	0.41	6.70	34
		Carrots	0.93	0.24	9.58	44
		Lettuce	1.36	0.15	2.87	18
		Tomato	0.88	0.20	3.89	21
		Lentils	24.63	1.06	63.35	361
		Pumpkin	1.00	0.10	6.5	31
		Corn	3.27	1.35	18.70	100
		Beets	1.61	0.17	9.56	46

[1]Nutrion facts were obtained from (56) USDA. United States Department of Agriculture [Internet]. [cited 2019 Mar 5]. p. USDA Food Composition Databases. Available from: https://ndb.nal.usda.gov/

4.6.6 Number of factors to be retained

Although researchers must make the subjective decision of how many of the factors should be kept, there are some elements to be considered while deciding on the number of components to be retained. This includes the scree plot, the variance explained, the strength of the resulting factors, interpretability of the resulting factors and the eigenvalue (93).

Eigenvalue represents how much a factor can explain the variance of the observed and recorded variables. A factor that has an eigenvalue of more than one indicates that the factor explains variance within the data more than any of its variables. Therefore, many statistical packages such as SPSS have a default choice of eigenvalue set at one (93). However, on many occasions, the number of factors that have an eigenvalue more than one is unrealistically large and does not reflect the researcher's initial theory or their expected model. Therefore, other approaches were developed to use the eigenvalue to obtain a reasonable number of factors. These approaches include the scree plot, the total variance explained and interpretability of the resulting patterns (96).

4.6.7 Calculating factors scores

Factor scores represent a score quantifying the participant's strength of adherence to each of the dietary patterns (88). Factor scores were calculated for each of the resulting dietary patterns by first multiplying the loading values (regression values) for each food item by the actual daily consumption for each participant. After that, the resulting values will be added together to generate the dietary scores for each participant (88).

4.6.8 Analysis of the resulting factors

The association between the resulting dietary factor scores and the demographic health characteristics of the participants was explored. These demographic characteristics included age, sex, T2D diagnosis, HbA1c level, education level, income status, physical activity, history of chronic diseases other than T2D, smoking status and having a family history of T2D.

Also, to identify statistically significant differences between groups of demographic variables, regression hypothesis testing was used for continuous variables such as age. OR with 95% confidence intervals was calculated for binary variables such as sex while ANOVA was used for other categorical variables such as education levels and income levels. If ANOVA hypothesis testing found enough statistical evidence to conclude a difference, Bonferroni post-hoc tests were used to find in which of the subgroups those differences were to be found. Bonferroni was chosen as a post-hoc test for ANOVA because it will yield more accurate results in comparing the mean of groups that have different sample sizes (100). The associations between the dietary factor scores and HbA1c scores excluding those with a T2D diagnosis was also explored.

All hypothesis testing was done at an alpha of 0.05 (p-value =<0.05 is significant) and 95% Cl. The assumptions for the multiple linear regressions were met for these analyses which are a linear relationship between the dependent and independent factors, normally distributed residuals, equal variances (homoscedasticity) and no or little multicollinearity among the data tested. The assumptions for ANOVA were also met, which are normality of distribution, equal variance and independence of samples.

4.7 Ethical approval, informed consent and data keeping

Ethical approval for the secondary data analysis was acquired from the School of Health and Related Research, Sheffield University (Appendix 6).

Ethical approval for the primary data collection was acquired before data collection from the public health committee for ethical approval in Medina, Saudi Arabia (Appendix 7). The thesis proposal, questionnaire and required forms were submitted through email. This research did not involve any invasive medical procedure except for capillary blood testing. All blood samples were collected using disposable finger sticks by trained licensed health care practitioners to avoid any risk to the participants.

4.7.1 Consent procedure

In addition to a verbal explanation, the participants were handed an information sheet explaining the nature of the research, anonymity and confidentiality of data collected, and how the data would be used. The language for this consent was in Arabic with English translation if necessary. The participants were informed about the need to collect a blood sample from the beginning. It was made clear to them that they could withdraw whenever they wanted during the interview. The written consent form is included in Appendix 3.

4.7.2 Research data keeping

To maintain the confidentiality of the data, all the filled-in surveys were kept in a locked briefcase all the time. The data were typed into an Excel database saved on a password-protected and encrypted hard drive that was only accessible to the researcher and research team with no participants' names included, ensuring anonymity.

4.8 Method chapter summary

Data from two cross-sectional studies were acquired for this study: The Saudi National Health Survey data (SNHS) (2013) (46), and primary data collected using a survey of clinic patients. The SNHS data is a nation-wide data set with an exceptionally large sample size focusing on a wide range of chronic diseases including type two diabetes (T2D); however, it has a limited 19-item FFQ. For the primary data collection, a smaller sample of participants from primary health clinics in Medina, Saudi Arabia, were recruited. For this study a more detailed 125 food items modified EPIC FFQ (85) previously used in another study (77) was used for data collection.

Similar items from the modified EPIC FFQ will be grouped together to be feasible for factor analysis and to be more feasible for descriptive analysis. Descriptive analysis will include participants' demographics and health characteristics and the FFQ food items daily consumption for each data set. Continuous variables will be presented as means and standard deviation while categorical variables will be presented as ratios.

Dietary patterns within each data set will be identified using PCA with varimax rotation. Scree plots were used to determine the number of factors retained. Afterwards, dietary pattern scores were calculated for each participant by adding the results of multiplying the mean daily consumption of food items by their factor loads within each dietary pattern.

Hypothesis testing will be carried out to explore the associations between the identified dietary pattern scores and T2D (being either diagnosed or undiagnosed), HbA1c level and BMI level. Furthermore, the association between the identified dietary pattern scores and various other demographic and health characteristics, such as age and gender or having a history of chronic diseases other than T2D, will be explored. All hypothesis testing was considered significant at a p-value of 0.05.

Chapter 5: Results

This chapter will display the descriptive and inferential analysis that resulted from exploring two sets of data. The first set of data are secondary data obtained from the 2013 Saudi National Health Interview Survey (SHIS) which will be explored in section one of this chapter. The second set will be survey data collected from clinic patients for which a modified EPIC FFQ was used (Appendix 2) which will be explored in section two of this chapter. For clarity, the data obtained from the SHIS will be labelled as the secondary data, while the data collected through interview surveys using the modified EPIC FFQ will be labelled as the primary data throughout this chapter. In section three of this chapter, the differences and similarities between the findings in the two survey populations will be presented and discussed.

Section One: Saudi National Health Interview Survey (SHIS) data analysis

First, this section will display the demographic and health characteristics ofthe secondary data study sample. After that, this section will explore the dietary data for the secondary data sample within the context of factor analysis. The resulting dietary patterns will also be explored in relation to the demographic and health characteristics which will allow us to understand the dietary consumption of different groups within the Saudi population. Furthermore, it will allow identification of dietary patterns which are more related to adverse health outcomes using statistical hypothesis testing. Exploring dietary patterns in relation to different demographic and health characteristics facilitates comparisons between the primary and secondary data despite the differences in the demographic characteristics and the dietary data collected.

More detailed descriptive analysis showing how the secondary data sample is distributed among different demographic and health variables can be found in Appendix 4. A full descriptive analysis showing the mean daily frequency of consumption of the FFQ food item stratified by demographic and health variables (age, gender, diabetes diagnosis status, HbA1C and BM, income status, education levels, smoking status, history of chronic diseases, and whether exercising regularly) and how the dietary patterns relate to smocking status, physical activity, having history of chronic disease other than T2D, education level and income level can also be found in Appendix 4.

5.1.1 Secondary data sample size

Among the sample of 10 821 participants in the Saudi NHIS, 808 (7.5%) reported a diagnosis of T2D, 154 (1.4%) reported a diagnosis of type 1 diabetes, 284 (2.6%) didn’t know their diabetic type, 400 (3.7%) had a diabetic level of HbA1c (6.5% or over) but no diabetes diagnosis and four did not respond to the question about diabetes type. Including those with a diabetic level of HbA1c but with no diabetic diagnosis, there was a total of 1208 (11.2%) T2D cases. After excluding type 1 diabetic cases and cases that did not respond or did not know their type of diabetes, the total number of non-diabetic participants was 9171. This suggests an overall crude prevalence of T2D in the survey population of 11.6%. It should be noted that this prevalence has only included T2D cases. This may explain why it is lower than the total diabetic prevalence of 13.6% reported in 2013 (46).

5.1.2 Secondary data demographic characteristics:

The demographic and socioeconomic data for the 10379 participants included for analysis are shown in Table 5.1 where only participants with type 1 diabetes and diabetics who did not know their diabetes type were excluded. The female to male ratio for the whole sample was roughly 1 to 1 with slightly more female participants (n=5301) (Figure 5.1). Men have a higher prevalence than women for both diagnosed and undiagnosed T2D. Diagnosed T2D individuals had the highest means for both age and BMI, whilst undiagnosed T2D individuals had higher means than non-diabetics for both age and BMI. Smoking prevalence was also highest among those diagnosed with T2D while their estimates of income were lower in comparison with the other two groups of undiagnosed T2D and non-diabetic individuals. Also, diabetic individuals had a lower level of education, took less exercise and had a higher prevalence of cardiovascular diseases than the other groups. The undiagnosed diabetic group took more exercise than the other two groups.

Table 5.1: Characteristics of participants included in the analysis of the secondary data stratified by diagnosis group and sex

Variable	Diagnosed T2D		Undiagnosed T2D		Non-diabetic		Total
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	
Sample size (No.)	477	331	199	201	4402	4769	10379
Age in years Mean (SD[1]) [range] **n=10718**	57 (14) [19-95]	56 (13) [19-100]	46 (18) [15-95]	41 (15) [15-100]	36 (15) [15-105]	35 (14) [15-101]	37 (16) [15-105]
BMI[2] Mean (SD[1]) [range] **n=10416**	29.5 (5.2) [18.9-53.8]	32.7 (6.1) [14.9-50.6]	28.5 (5.4) [15.6-50.7]	30.8 (6.5) [18.8-52.7]	26.8 (5.7) [11.6-53.4]	28.0 (6.4) [12.6-55.5]	27.8 (6.3) [11.6-75.6]
HbA1c Mean (SD[1]) [range] **n=4461**	7.0 (2.0) [3.0-13.0]	7.0 (2.0) [4.0-13.0]	8.0 (1.0) [7.0-13.0]	8.0(2.0) [7.0-14.0]	5.0 (0) [2.0-6.0]	5.0 (0) [2.0-6.0]	6.0 (1.0) 2.0-21.0
Exercise regularly (Column N %) **n=10821**	4.4	2.1	10.9	2.5	2.6	2.6	9
Smoking (Column N %) **n=10788**	34.4	3.0	24.5	1.0	2.4	2.4	17.0

[1]SD: Standard deviation, [2]BMI: Body mass index, [3]SAR: Saudi ryals.

Table 5.1 continued

	Diagnosed T2D		Undiagnosed T2D		Non-diabetic		Total
	Male	Female	Male	Female	Male	Female	
Monthly income estimate in SAR[3] (Column N %)							
< 5000	35.7	50.0	27.1	35.3	38.3	38.3	35.2
5000 – 10,000	32.2	30.5	40.0	36.7	35.3	35.3	35.7
10,000 – 15,000	16.5	9.3	15.9	10.8	15.1	15.1	16.1
15,000 – 20,000	10.2	4.5	9.4	10.1	7.0	7.0	7.6
> 20,000	5.4	5.7	7.6	7.2	4.3	4.3	5.3
n=8886							
Level of education (Column N %)							
Illiterate	14.1	54.4	11.4	30.7	15.5	15.5	12.5
Literate but no school education	13.7	12.1	9.5	11.6	7.2	7.2	6.3
Primary school	19.4	10.0	10.0	7.0	10.2	10.2	10.5
Middle school	17.1	7.3	22.9	13.1	15.4	15.4	16.6
High school	18.7	9.7	20.9	17.1	26.5	26.5	28.6
Bachelor degree	14.9	5.7	23.9	19.6	24.2	24.2	22.9
Postgraduate degree	2.1	0.9	1.5	1.0	1.0	1.0	1.5
n=10821							
History of chronic heart disease (Column N %)							
n=10821	1.0	0.3	0.5	0	0.3	0.3	0.3

[1]SD: Standard deviation, [2]BMI: Body mass index, [3]SAR: Saudi ryals

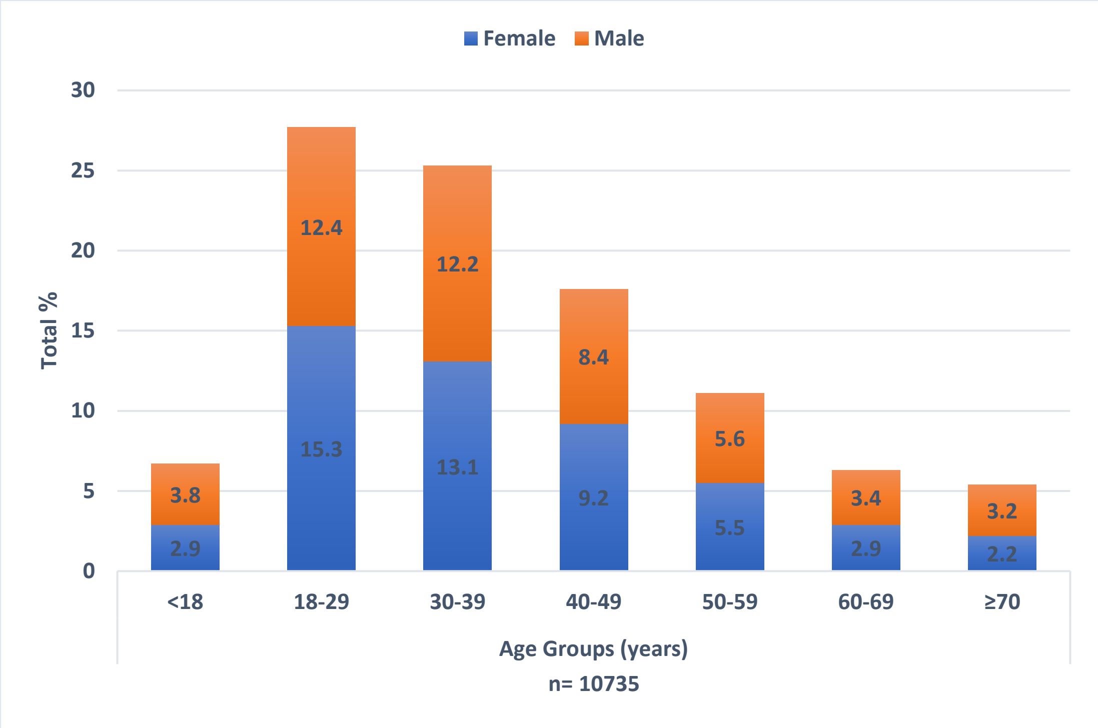

Figure 5.1: Distribution of the secondary data sample by sex and age group

5.1.3 Secondary data FFQ dietary item mean frequencies of consumption per day

Figure 5.2 displays the mean frequency of consumption for food items per day. There are 18 food items in total of which most are broad categories such as "fruits" and "vegetables". The most frequently consumed items were poultry (1.16 per day) followed by vegetables (1.08 per day). The least consumed items were shrimp (0.04 per day) followed by processed meat (0.08) per day.

Given the nature of the FFQ structure (where zero is the most reported value for each food item), the distribution of all the food items are skewed to the left; hence, measure for spread such as SD will not be provided since they are not accurate for skewed data. Tables containing the means and SD for the dietary consumption data can be found in Appendix 4.

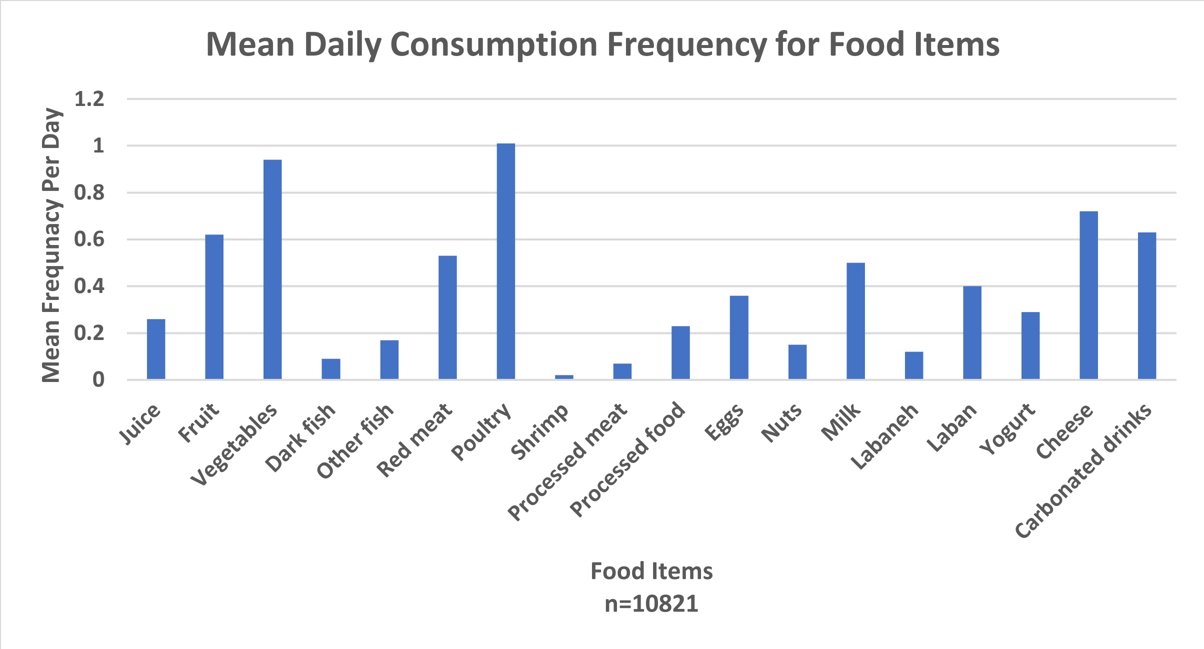

Figure 5.2: Mean frequency of consumption per day of the food items in the secondary data

5.1.4 Secondary data principal Component Analysis and the resulting dietary patterns

As a first step in carrying out the secondary data PCA, First, Bartlett's Test of Sphericity was conducted resulting in a p-value less than 0.001; thus, it demonstrates that the variable is suitable for structure detection within the factor analysis. To measure the adequacy of sample size for the intended PCA, Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was done resulting in a value of 0.82 indicating that the sample size was both adequate and in the desirable range (101).

Exploratory factor analysis was done to identify the best structure for the dietary patterns. The first step was to do PCA with oblique rotation to identify the correlation matrix which can indicate whether oblique or orthogonal rotation was more appropriate. Direct Oblimin rotation is an oblique rotation that will result in a more accurate factor analysis solution if the components are correlated with each other (102).

However, upon doing PCA with Direct Oblimin rotation, the resulting component correlation matrix showed that there is a very low correlation between the resulting nine components that have an eigenvalue exceeding one. The results shown in Table 5.2 indicate that the components are not suitable for an oblique rotation due to having poorly correlated factors and therefore an orthogonal rotation would result in a more accurate solution.

Tables 5.2: Secondary data PCA correlation matrix

Component	**1**	**2**	**3**	**4**
1	1	0.116	-0.17	0.251
2	0.116	1	-0.169	0.092
3	-0.17	-0.169	1	-0.125
4	0.251	0.092	-0.125	1

Extraction Method: Principal Component Analysis.

Rotation Method: Oblimin with Kaiser Normalization.

The PCA for secondary data resulted in only four factors with eigenvalues that are above one; hence, all the four factors were retained. No food items within the patterns had less than 0.1 loadings in all resulting patterns and therefore no food items have been removed to find the best solution (88). The four factors structure explained 42.8% of the variation within the data. Each of the five factors has at least 6.34% of the variance explained and an eigenvalue exceeding 1.1 (Figure 5. 3).

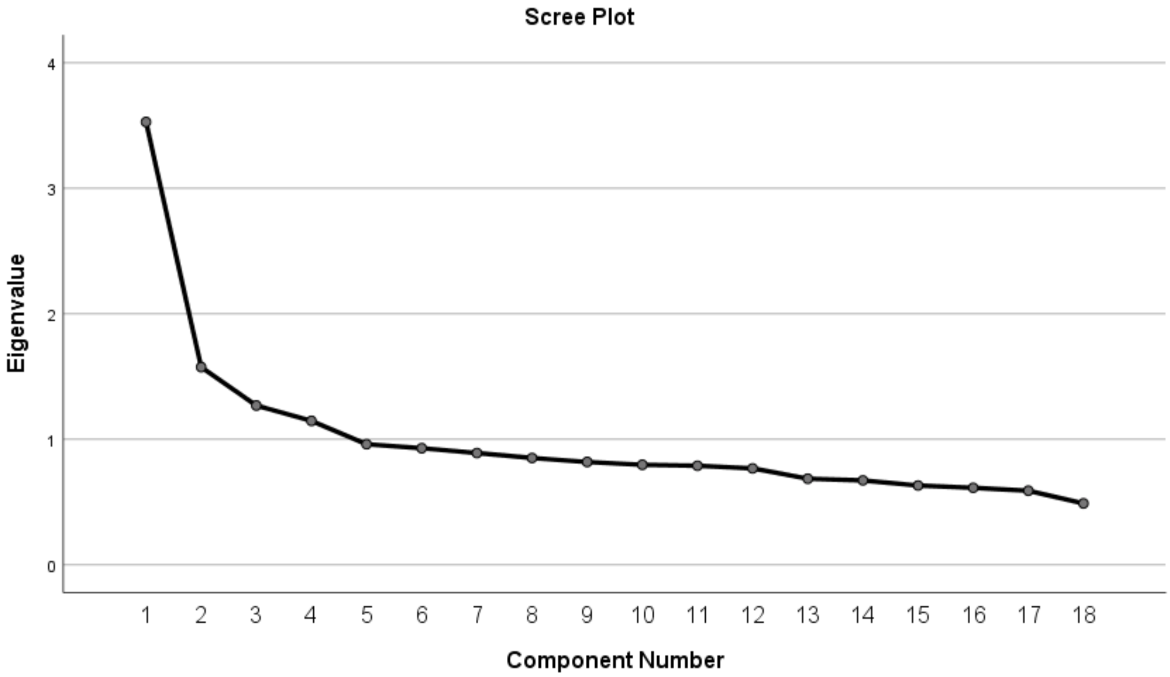

Figure 5.3: Scree plot of the secondary data PCA

For simplicity and ease of comparison, the identified dietary patterns were named according to their prominent food items as “Traditional”, “Dairy Products”, “Seafood” and “Fast Food” dietary patterns (Table 5.3).

Table 5.3: The results of primary data PCA with Varimax rotation at a fixed number of factors of five

	1 Traditional	2 Dairy Products	3 Seafood	4 Fast Food
Juice	**0.421**	**-**	**0.335**	**-**
Fruit	**0.586**	**-**	**0.393**	**-**
Vegetables	**0.673**	**-**	**-**	**-**
Dark Fish	**-**	**-**	**0.4**	**-**
Other Fish	**-**	**-**	**0.652**	**-**
Red Meat	**0.487**	**-**	**-**	**-**
Poultry	**0.581**	**-**	**-**	**-**
Shrimp	**-**	**-**	**0.587**	**-**
Processed Meat	**-**	**-**	**0.464**	**0.415**
Processed Food	**-**	**-**	**-**	**0.69**
Eggs	**-**	**0.509**	**-**	**-**
Nuts	**-**	**-**	**0.33**	**0.445**
Milk	**0.583**	**0.365**	**-**	**-**
Labneh	**-**	**0.688**	**-**	**-**
Laban	**0.478**	**0.43**	**-**	**-**
Yoghurt	**-**	**0.605**	**-**	**-**
Cheese	**-**	**0.613**	**-**	**-**
Carbonated Drinks	**-**	**-**	**-**	**0.719**

*Only values above 0.3 are showing

Dietary patterns scores were calculated from those four identified patterns where their means and SD can be seen in Figure 5.4 and Table 5.4. Those dietary scores reflect the degree to which participants adhere to the identified dietary pattern. Figure 5.4 and Table 5.4 show that the dietary pattern with the most adherence within the secondary data sample is the Traditional dietary pattern, followed by Dairy Products, Fast Food and lastly the Seafood dietary patterns.

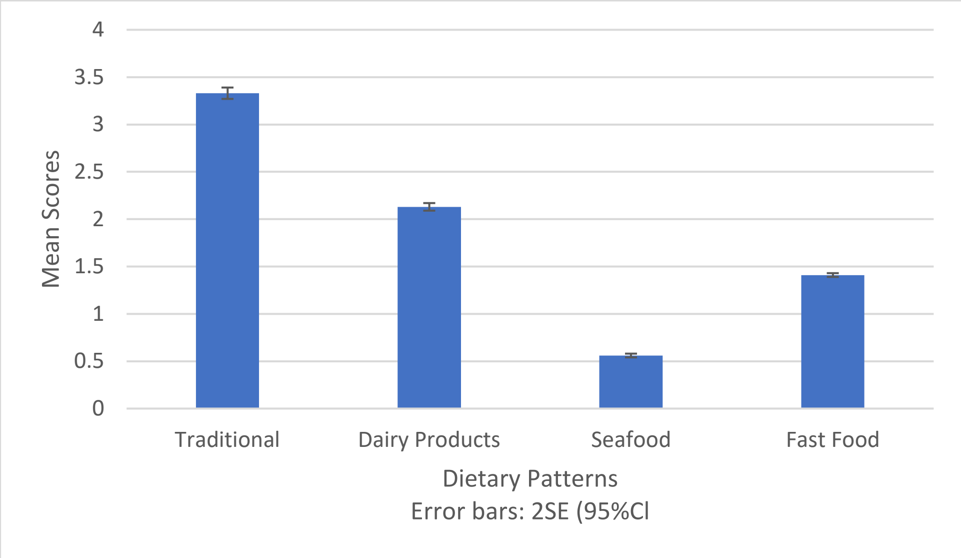

Figure 5.4: Mean secondary data dietary pattern scores

Table 5.4: Mean and standard deviation for the secondary data dietary patterns scores

	Mean	SD
Traditional	3.33	2.36
Dairy Products	2.13	1.64
Seafood	0.56	0.73
Fast Food	1.41	1.25

5.1.5 Age groups association with the secondary data dietary patterns

The distribution for the secondary data mean dietary pattern scores by age group shows that there are relatively similar mean scores for the Traditional and Seafood dietary patterns. For the Dairy Products and Fast Food patterns, there is a trend towards high dietary pattern scores for the younger age groups that decrease gradually among older participants, however, the size of the association between age and dairy products is very small (Figure 5.5 and Table 5.5).

On examining the relationship between age and dietary pattern scores using a linear regression hypothesis test, both Dairy Products and Fast Food dietary patterns were found to be statistically significant and negatively associated with an increase in age (*b* (p-value)= -0.077 (>0.001) and -0.310 (>0.001) respectively). The Seafood dietary pattern was statistically significant and positively associated with the increase in age (*b* (p-value) = 0.243 (0.044)) (table 5.5)

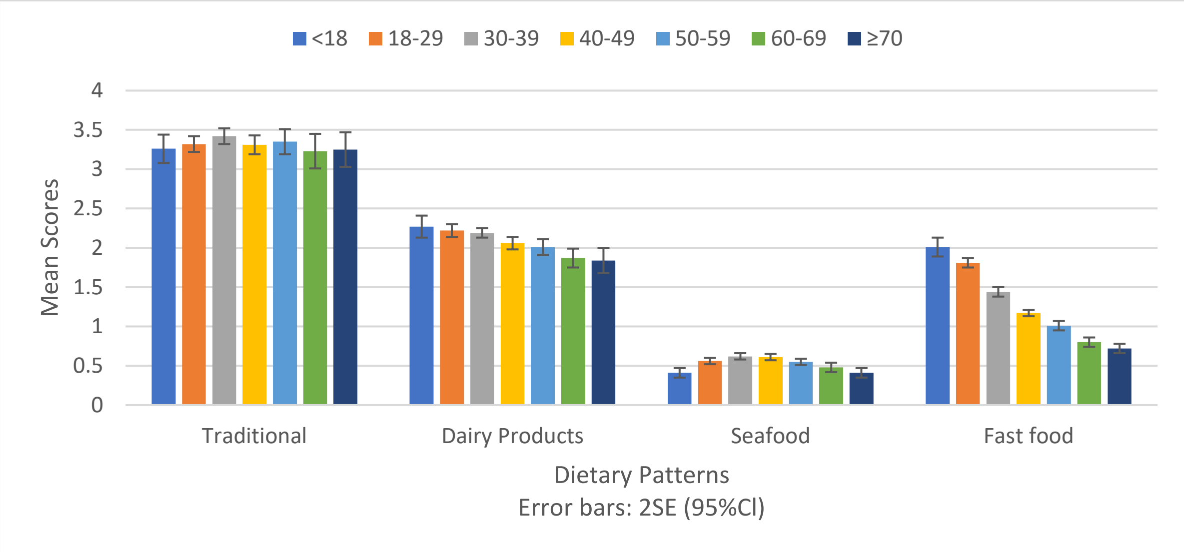

Figure 5.5: Secondary data mean dietary pattern scores stratified by age group

Table 5.5: Secondary data dietary pattern score means, standard deviations and linear regression results while stratified by age group

	Traditional		**Dairy Products**		**Seafood**		**Fast Food**	
	M	SD	M	SD	M	SD	M	SD
<18	3.26	2.12	2.27	1.66	0.41	0.63	2.01	1.45
18-29	3.32	2.4	2.22	1.7	0.56	0.74	1.81	1.48
30-39	3.42	2.3	2.19	1.59	0.62	0.73	1.44	1.18
40-49	3.31	2.33	2.06	1.63	0.61	0.76	1.17	0.94
50-59	3.35	2.48	2.01	1.65	0.55	0.7	1.01	0.94
60-69	3.23	2.48	1.87	1.48	0.48	0.72	0.8	0.67
≥70	3.25	2.45	1.84	1.63	0.41	0.7	0.72	0.75
***b* (p-value)**	0.075 (0.342)		**-0.077 (>0.001)**		**0.243 (0.044)**		**-0.310 (>0.001)**	

5.1.6 Sex association with the secondary data dietary patterns

Males scored higher for the Traditional and Fast Food dietary patterns compared to females. Both sexes had very similar scores for the Dairy Products and Seafood dietary patterns (Figure 5.6 and Table 5.6).

Logistic regression hypothesis testing reveals that those who scored high in the Traditional and Fast Food dietary patterns have higher odds of being male (OR (CI) = 1.040 (1.021-1.059) and 1.164 (1.123-1.207) respectively) This association continues to present after adjusting for age (OR (CI) = 1.040 (1.021-1.060) and 1.220 (1.173-1.269) respectively) (Table 5.6).

Figure 5.6: Secondary data mean dietary pattern scores stratified by sex

Table 5.6: Secondary data dietary pattern score mean, standard deviation and odd ratio results while stratified by age group

	Female		Male		*OR of being male (95%Cl)*	
	M	**SD**	**M**	**SD**	**Model 1***	**Model 2****
Traditional	3.22	2.36	3.44	2.36	**1.040 (1.021-1.059)**	**1.040 (1.021-1.060)**
Dairy Products	2.15	1.7	2.1	1.58	0.980 (0.954-1.006)	0.984 (0.958-1.008)
Seafood	0.55	0.73	0.57	0.72	1.045 (0.985-1.108)	1.048 (0.988-1.112)
Fast Food	1.29	1.18	1.52	1.3	**1.164 (1.123-1.207)**	**1.220 (1.173-1.269)**

*Unadjusted, **Adjusted to age

5.1.7 Diagnosis groups association with the secondary data dietary patterns

On exploring the relationship between primary data dietary pattern scores and the diagnosis groups, the non-diabetic scored highest for the Fast Food dietary pattern in comparison with other groups, which is expected since the Fast Food dietary pattern was significantly associated with lower age groups where having a diagnosis of T2D is less common. The undiagnosed diabetic scored highest for the Traditional dietary pattern while all the diagnosis groups had relatively similar scores for the Dairy Products and Seafood dietary patterns (Figure 5.7 and Table 5.7).

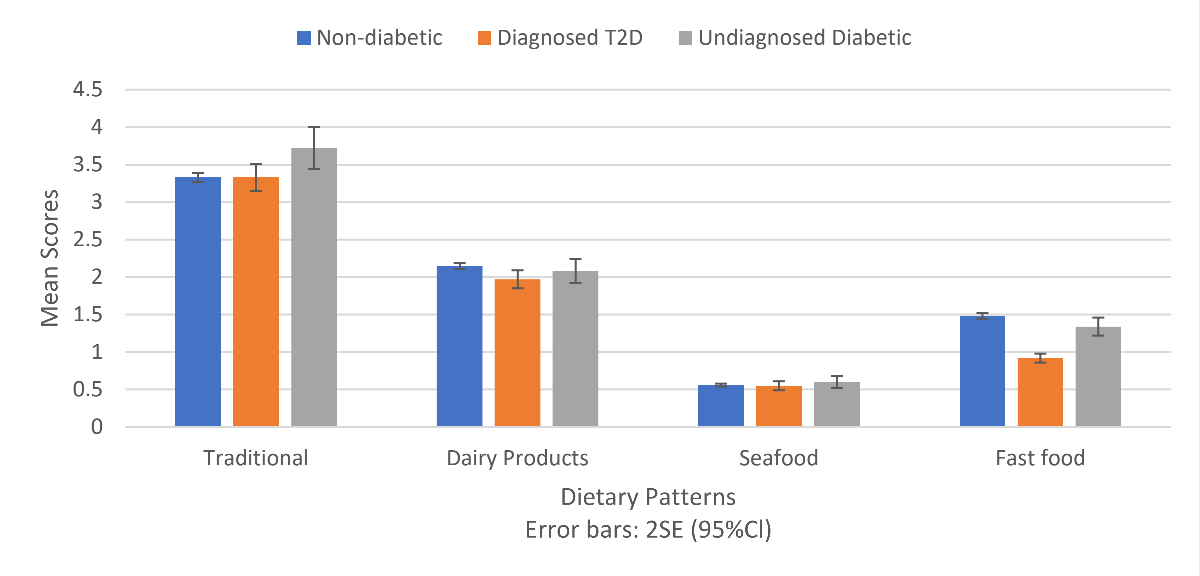

Figure 5.7: Secondary data mean dietary pattern scores stratified by diagnosis group

While examining the OR of having T2D (Table 5.8), participants who scored higher in the Dairy Products dietary pattern had lower odds of being diagnosed with T2D (OR=0.919, 95%Cl=0.866-0.976); however, the statistical significance of this association is lost after controlling for age and sex (Table 5.9). Also, participants who scored higher in the Fast Food dietary pattern had lower odds of being diagnosed with T2D (OR=0.502, 95%CI=0.444-0.566). This association continues to present after controlling for age and sex (OR=0.854, 95%CI=0.765-0.952) and additionally after controlling for smoking status and exercising regularly (OR=0.855, 95%CI=0.766-0.954) (Table 5.8).

The OR of being undiagnosed diabetic shows that participants who scored high in the Traditional dietary pattern have higher odds of being undiagnosed diabetic (OR=1.059, 95%Cl=1.018-1.101) even after controlling for age and sex (OR=1.062, 95%Cl=1.022-1.104) and additionally after controlling for smoking status and exercising regularly (OR=1.061, 95%Cl=1.020-1.103) (Table 5.7).

Table 5.7: Secondary data dietary pattern score means and standard deviations stratified by diagnosis group

	Non-diabetic		Diagnosed T2D		Undiagnosed Diabetic	
	M	**SD**	**M**	**SD**	**M**	**SD**
Traditional	3.33	2.35	3.33	2.38	3.72	2.6
Dairy Products	2.15	1.66	1.97	1.62	2.08	1.42
Seafood	0.56	0.73	0.55	0.68	0.6	0.77
Fast Food	1.48	1.28	0.92	0.9	1.34	1.05

Table 5.8: Secondary data dietary patterns odd ratios of being diagnosed T2D or undiagnosed diabetic

	OR of being T2D (95%Cl)			OR of being undiagnosed diabetic (95%Cl)		
	Model 1[1]	**Model 2[2]**	**Model 3[3]**	**Model 1[1]**	**Model 2[2]**	**Model 3[3]**
Traditional	0.997 (0.963-1.1031)	1.005 (0.969-1.042)	1.007 (0.971-1.944)	**1.059 (1.018-1.101)**	**1.062 (1.022-1.104)**	**1.061 (1.020-1.103)**
Dairy Products	**0.919 (0.866-0.976)**	0.997 (0.943-1.054)	0.999 (0.946-1.056)	0.969 (0.900-1.044)	0.996 (0.929-1.069)	0.996 (0.928-1.069)
Seafood	0.971 (0.869-1.086)	1.100 (0.978-1.236)	1.101 (0.978-1.238)	1.059 (0.915-1.225)	1.082 (0.937-1.250)	1.088 (0.942-1.257)
Fast Food	**0.502 (0.444-0.566)**	**0.854 (0.765-0.952)**	**0.855 (0.766-0.954)**	0.906 (0.819-1.004)	1.039 (0.944-1.144)	1.043 (0.948-1.149)

[1]Unadjusted, [2]Adjusted to age and sex, [3]Adjusted to age, sex, smoking status and exercising regularly

5.1.8 HbA1c levels association with the secondary data dietary patterns

The distribution of the dietary pattern scores among HbA1c levels shows that those with diabetic levels of HbA1c score highest for the Traditional dietary patterns compared to the other levels of HbA1c. There were very similar scores between HbA1c levels for the Dairy Products, Seafood and Fast Food dietary patterns (Figure 5.8 and Table 5.9).

By examining the relationship between dietary pattern scores and HbA1c levels using linear regression, the Traditional dietary patterns were positively but weakly associated with HbA1c levels [*b* (b-value) = 0.039 (0.024)] even after adjusting for age and sex [*b* (b-value) = 0.041 (0.014)], and additionally adjusting for smoking status and exercising regularly [*b* (b-value) = 0.040 (0.017)] (table 5.9). In contrast, the Fast Food dietary pattern was negatively but also weakly associated with HbA1c level [*b* (p-value) = -0.072 (<0.001)]; however, the statistical significance for this association is lost after adjusting for age and sex (Table 5.9).

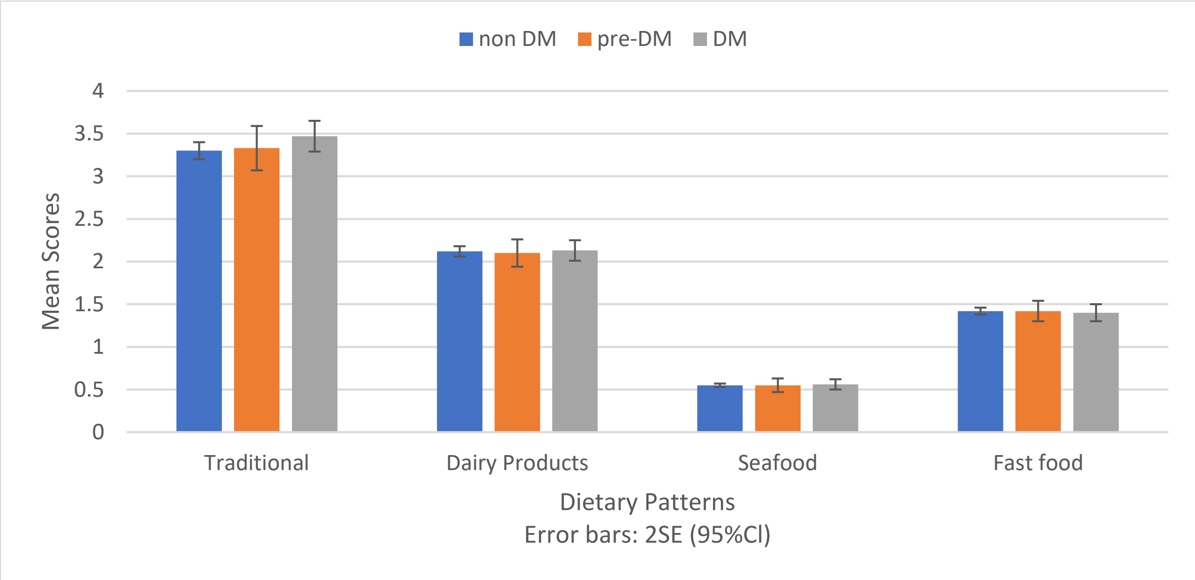

Figure 5.8: Secondary data mean dietary pattern scores stratified by HbA1c level

Table 5.9: Secondary data dietary pattern score mean, standard deviation and linear regression results stratified by HbA1c level

	Non- DM		Pre-DM		DM		***b* (p-value)**		
	M	**SD**	**M**	**SD**	**M**	**SD**	**Model 1[1]**	**Model 2[2]**	**Model 3[3]**
Traditional	3.3	2.33	3.33	2.32	3.47	2.29	**0.039 (0.024)**	**0.041 (0.014)**	**0.040 (0.017)**
Dairy Products	2.12	1.62	2.1	1.49	2.13	1.53	-0.009 (0.596)	0.014 (0.410)	0.812 (0.417)
Seafood	0.55	0.7	0.55	0.74	0.56	0.69	0.018 (0.291)	0.030 (0.074)	0.030 (0.068)
Fast Food	1.42	1.28	1.42	1.12	1.4	1.18	**-0.072 (<0.001)**	0.009 (0.593)	0.009 (0.616)

[1]Unadjusted, [2]Adjusted to age and sex, [3]Adjusted to age, sex, smoking status and exercising regularly

5.1.9 HbA1c levels excluding those diagnosed with T2D association with the secondary data dietary patterns

While excluding those diagnosed with T2D who are on glucose controlling medication, the distribution of the dietary pattern scores by HbA1c level shows that this time, those with diabetic levels of HbA1c scored highest for the Traditional and Dairy Products dietary patterns compared to the other levels of HbA1c. All levels of HbA1c had closely similar scores for the Seafood and Fast Food dietary patterns (Figure 5.9 and Table 5.10).

By examining the relationship between dietary pattern scores and HbA1c levels using linear regression (after excluding those diagnosed with T2D), there was a statistically significant negative and weak association found between HbA1c level and the Fast Food dietary pattern score (*b*= -0.040, p-value= 0.027); however, the statistical significance for this association is lost after adjusting for age and sex (Table 5.10).

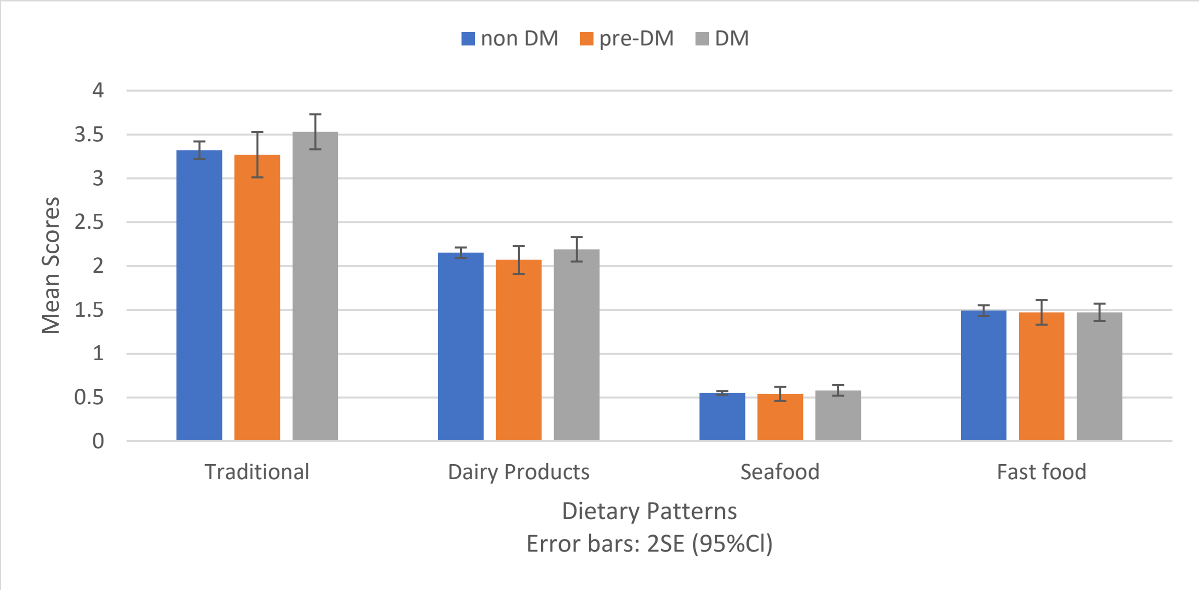

Figure 5.9: Secondary data mean dietary pattern scores stratified by HbA1c level after excluding those diagnosed with T2D

Table 5.10: Secondary data dietary pattern score mean, standard deviation and linear regression results stratified by HbA1c level after excluding those diagnosed with T2D

	Non- DM		**pre-DM**		**DM**		***b* (p-value)**		
	M	**SD**	**M**	**SD**	**M**	**SD**	**Model 1[1]**	**Model 2[2]**	**Model 3[3]**
Traditional	3.32	2.34	3.27	2.12	3.53	2.35	0.029 (0.113)	0.030 (0.096)	0.029 (0.105)
Dairy Products	2.15	1.64	2.07	1.36	2.19	1.58	-0.022 (0.227)	-0.006 (0.716)	-0.006 (0.725)
Seafood	0.55	0.71	0.54	0.72	0.58	0.7	0.011 (0.528)	0.018 (0.309)	0.020 (0.263)
Fast Food	1.49	1.32	1.47	1.13	1.47	1.21	**-0.040 (0.027)**	0.013 (0.496)	0.014 (0.450)

[1]Unadjusted, [2]Adjusted to age and sex, [3]Adjusted to age, sex, smoking status and exercising regularly

5.1.10 Body Mass Index levels association with the secondary data dietary patterns

On examining the distribution of the dietary pattern scores by BMI level, those with overweight and obese levels of BMI (>25 kg/m^2) scored highest in the Traditional and Seafood dietary patterns. Those who are underweight or normal levels of BMI (<24.9 kg/m^2) scored highest in the Fast Food dietary pattern (Figure 5.10 and Table 5.11).

Using linear regression, the relationships between BMI levels and the dietary pattern scores were explored. All dietary patterns were positively but extremely weakly associated with BMI after adjusting for age and sex; this relationship continued to be statistically significant after controlling for smoking status and exercising regularly (Table 5.11).

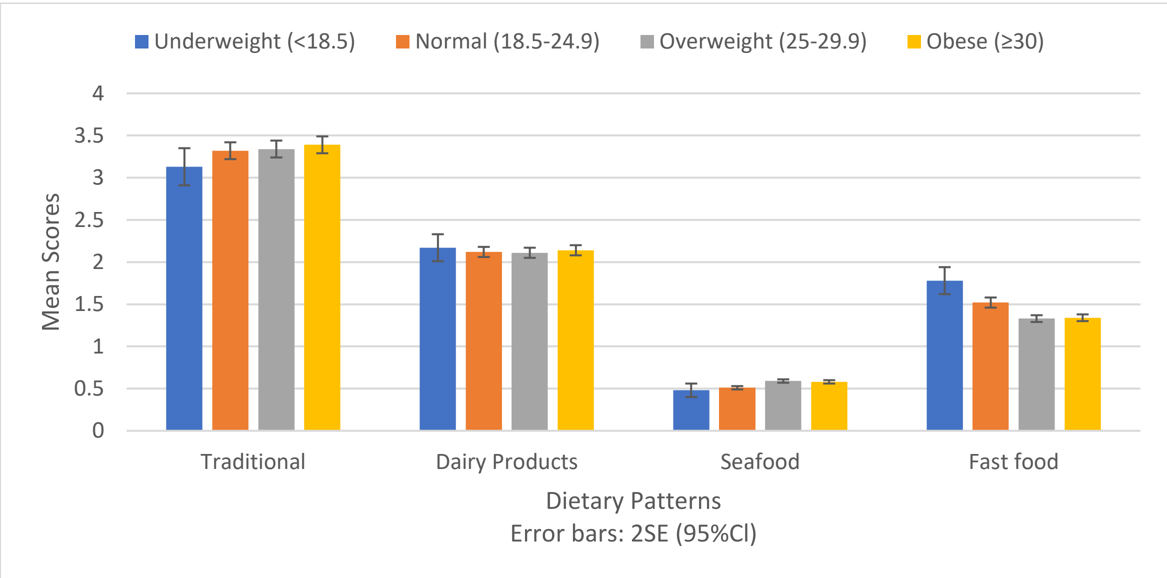

Figure 5.10: Secondary data mean dietary pattern scores stratified by BMI level

Table 5.11: Secondary data dietary pattern score mean, standard deviation and linear regression results stratified by BMI level

	Underweight (<18.5)		Normal (18.5-24.9)		Overweight (25-29.9)		Obese (≥30)		*b* (p-value)		
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**Model 1[1]**	**Model 2[2]**	**Model 3[3]**
Traditional	3.13	2.1	3.32	2.33	3.34	2.35	3.39	2.43	**0.025 (0.026)**	**0.032 (0.003)**	**0.034 (0.002)**
Dairy Products	2.17	1.54	2.12	1.58	2.11	1.57	2.14	1.76	0.016 (0.159)	**0.033 (0.003)**	**0.034 (0.002)**
Seafood	0.48	0.78	0.51	0.68	0.59	0.74	0.58	0.74	**0.039 (<0.001)**	**0.046 (<0.001)**	**0.048 (0.001)**
Fast Food	1.78	1.6	1.52	1.28	1.33	1.13	1.34	1.25	**-0.061 (<0.001)**	**0.034 (0.003)**	**0.039 (0.001)**

[1]Unadjusted, [2]Adjusted to age and sex, [3]Adjusted to age, sex, smoking status and exercising regularly

5.1.11 Section one summary

Four dietary patterns were identified within the secondary data sample using the SHIS 18 items FFQ. The four patterns were named according to some of their features as Traditional, Dairy Products, Seafood, and Fast Food dietary patterns (Figure 5.11).

The Traditional dietary pattern was common among males before and after adjusting for age (OR=1.040, 95%CI=1.021-1.060). It was also more common among the undiagnosed diabetic participants after controlling for age and sex (OR=1.062, 95%CI=1.022-1.104). The Traditional dietary pattern was also positively associated with HbA1c values after adjusting for age and sex (*b*=0.041, p-value=0.014); however, this association is lost after excluding participants with a T2D diagnosis. The Traditional dietary pattern was also associated with higher BMI levels after adjusting for age and sex (*b*=0.032, p-value=0.003). Additionally, there was no significant association between the Traditional dietary pattern and age, which might suggest that it is equally common across all age groups.

The Dairy Products dietary pattern was found to be negatively associated with increased age (*b*=-0.077, p =<0.001), however, the size of the association was very small. It was also associated with higher BMI levels after adjusting for age and sex (*b*=0.033, p=0.003).

The Seafood dietary pattern was positively associated with increase in age (*b*= 0.243, p-value=0.044). It was also associated with higher BMI levels (*b*=0.046, p-value=<0.0001 after adjusting for age and sex).

The Fast Food dietary pattern was found to be negatively associated with increased age (*b*=-0.077, p-value=<0.001). It was also found to be more common among males (OR=1.220, 95%CI=1.173-1.269 after adjusting to age). The Fast Food dietary pattern was less common among the diagnosed diabetic participants (OR=0.854, 95%CI=0.765-0.952 after controlling for age and sex). It was also associated with higher BMI levels (*b*=0.030, p-value=0.007 after adjusting for age and sex).

Highlighted finding from appendix 4 which contain additional analyses of the secondary data is that the Fast Food and Seafood dietary pattern were more common among smokers than non-smokers after adjusting for age and sex (OR=1.116, 95%CI=1.063-1.172 and OR=1.181, 95%CI=1.087-1.283 respectively). Additionally, both the Fast Food and Seafood dietary patterns were also more common among participants with a family history of T2D after adjusting for age and sex (OR=1.264, 95%CI=1.072-1.490 and OR=1.287, 95%CI=1.032-1.606 respectively). Regarding the distribution of the single FFQ food items by health and demographic variables in appendix 4, there were no prominent differences in consumption of food items except that fizzy drinks were more common among young age groups.

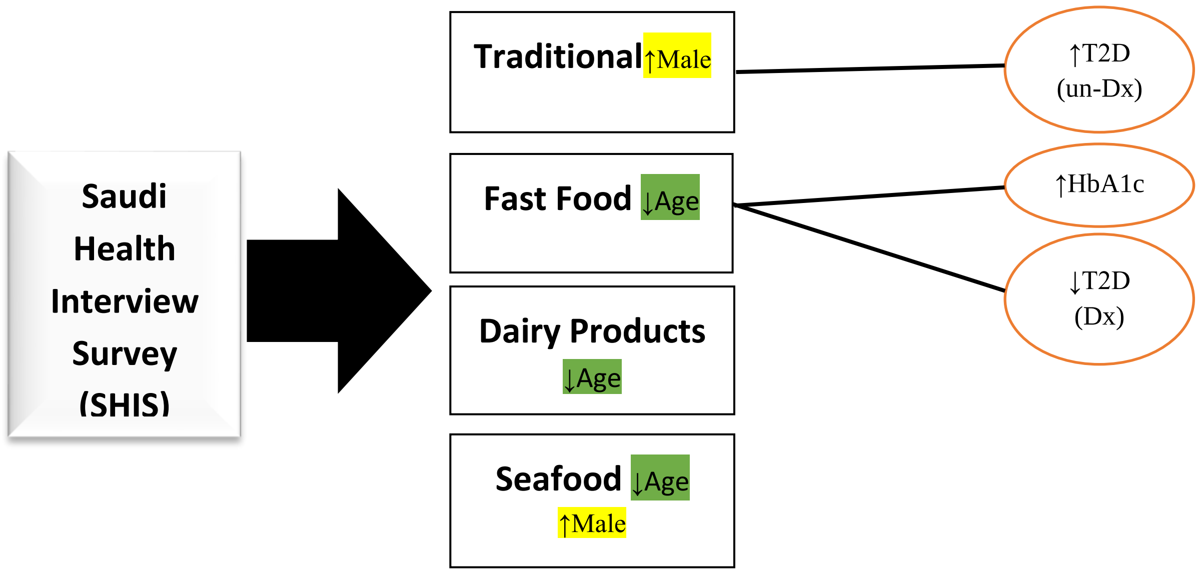

Figure 5.11: Summary of key associations between the SNHS dietary patterns and T2D, HbA1c and BMI levels, sex and age (Dx: diagnosed, un-Dx: undiagnosed)

Section two: Primary collected data analysis

As with section one, this section will first display the demographic and health characteristics of the sample of the primary data study sample. After that, this section will explore diet for the primary data sample within the context of factor analysis. The resulting dietary patterns will also be explored in relation to the demographic and health characteristics which will allow us to understand the dietary consumption of different groups within the Saudi population. Furthermore, it will allow identification of dietary patterns which are more related to adverse health outcomes using statistical hypothesis testing. Exploring dietary patterns in relation to different demographic and health characteristics facilitates comparisons between the primary and secondary data despite the differences in their demographic characteristics and the dietary data collected.

More detailed descriptive analysis showing how the secondary data sample is distributed among different demographic and health variables can be found in appendix 5. Also, more descriptive analysis showing the mean daily frequency of consumption of the FFQ food item stratified by the demographic and health variables such as age, gender, diabetes diagnosis status, HbA1C and BM, income status, education levels, smoking status, history of chronic diseases, exercising regularly and how the dietary patterns relate to smocking status, physical activity, having history of chronic disease other than T2D, education level and income level can also be found in Appendix 5.

5.2.1 Primary data sample:

The total number of participants recruited for this study was 234. However, HbA1c results were missing or unavailable for 19 of the participants. Among those, 9 participants had a definitive T2D diagnosis and therefore it was possible to group them with the participants with a T2D diagnosis when stratifying by diagnosis groups (for non-diabetics, undiagnosed diabetics and diagnosed T2D). The other 10 with no reported HbA1c results or definitive T2D diagnosis were excluded from the statistical analysis that involves stratifying the data by diagnostic groups because it was unknown whether they had undiagnosed diabetes or not and therefore which of the three analysis groups they should be included in. However, the total sample of 234 was used in factor analysis to identify the dietary patterns for the total sample and other analysis that did not require stratifying the data by diagnosis group.

5.2.2 Primary data demographic characteristics:

Among the 224 included in the statistical analysis stratified by diagnosis groups, there were 151 cases of diagnosed T2D, 60 cases of non-diabetics (no diabetic diagnosis and normal HbA1c levels) and 13 cases of undiagnosed T2D (no diabetic diagnosis but a diabetic level of HbA1c) (Table 5.15). The mean age for participants was 47.8 years (SD=15.0). Participants with a T2D diagnosis were older (M=54.83, SD=12.2) in comparison with the undiagnosed diabetics (M=34.9, SD=15.4) and non-diabetics (M=33.7, SD=8.0). The female to male ratio for the whole sample was 1.5 to 1 with more female participants in all age groups except 30-39 (Figure 5.2). The mean BMI for all participants was 29.8 kg/m^2 (SD=5.3) and the mean HbA1c for all participants was 7.4% (SD=2.1). Furthermore, 75.6% of participants reported having a family member with a T2D diagnosis while 44.9% reported having a chronic disease other than T2D. Moreover, among the 224 participants, 25.6% were non-diabetic, 5.6% were found to be undiagnosed diabetics and 64.5% reported having a diagnosis of T2D. Table 5.12 shows further characteristics for participants stratified by both sex and T2D diagnosis status while Figure 5.12 shows the distribution of the secondary data sample by age group and sex.

Table 5.12: Characteristics of participants included in the analysis of the primary data stratified by diagnosis group and sex

Variable	Diagnosed T2D		undiagnosed T2D		Non-diabetic		Total
	Male	Female	Male	Female	Male	Female	
Sample size (No.)	40	111	7	6	42	18	224
Age in years Mean (SD[1]) [range] **n=224**	56.4 (11.4) [33.0-83.0]	54.3 (12.5) [15.0-83.0]	42.2 (14.0) [30-68.0]	27.7 (14.1) [17.0-55.0]	32.7 (6.1) [19.0-52.0]	35.7 (10.8) [22.0-55.0]	48.27 (15.0) [15.0-83.0]
BMI[2] Mean (SD[1]) [range] **n=224**	28.5 (4.4) [17.7-37.4]	30.1 (5.5) [20.1-46.2]	35.0 (9.0) [26.8-50.5]	27.4 (6.1) [19.8-36.2]	29.1 (5.2) [21.2-41.2]	29.2 (6.2) [20.3-45.8]	29.9 (5.3) [17.7-45.8]
HbA1c level Mean (SD[1]) [range] **n=224**	8.2 (1.5) [6.1-14.0]	8.3 (2.1) [4.0-15.0]	7.5 (1.3) [6.5-10.2]	7.8 (1.3) [6.5-10]	5.4 (0.5) [4.4-6.4]	4.9 (0.5) [4.2-5.9]	7.4 (2.1) [4.0-15.0]
Exercise regularly (Column N %) **n=224**	25.0	40.5	42.9	66.7	40.5	38.9	38.4
Smoking (Column %) **n=220**	42.5	8.2	57.1	0	38.1	5.6	47

[1]SD: Standard deviation, [2]BMI: Body mass index, [3]SAR: Saudi ryals.

Table 5.12 continued

Variable	Diagnosed T2D		undiagnosed T2D		Non-diabetic		Total
	Male	Female	Male	Female	Male	Female	
Monthly income estimate in SAR[3] (Column N %)							
< 5000	22.9	44.6	0	25.0	7.9	14.3	28.9
5000 – 10,000	34.3	33.7	14.3	25.0	15.8	42.9	30.0
10,000 – 15,000	20	13.0	57.1	0	34.2	14.3	20.0
15,000 – 20,000	17.1	6.5	28.6	50	28.9	28.6	16.3
> 20,000	5.7	2.2	0	0	13.2	0	4.7
n=190							
Level of education (Column N %)							
Illiterate	0	39.6	0	16.7	0	5.6	20.5
Literate with no school education	5.0	7.2	0	0	0	0	4.5
Primary school	5.0	9.9	0	0	0	0	5.8
Middle school	10	4.5	14.3	0	0	0	4.5
High school	37.5	17.1	0	50	16.7	27.8	21.9
Bachelor degree	40	19.8	85.7	33.3	52.4	61.1	35.3
Postgraduate degree	2.5	1.8	0	0	31.0	5.6	7.6
n=224							
Family history of T2D (Column N %) **n=220**	80	76.6	71.4	83.3	76.2	77.8	77.3
History of chronic diseases other than T2D (Column N %) **n=223**	75.0	72.1	50	50	7.9	27.8	46.0

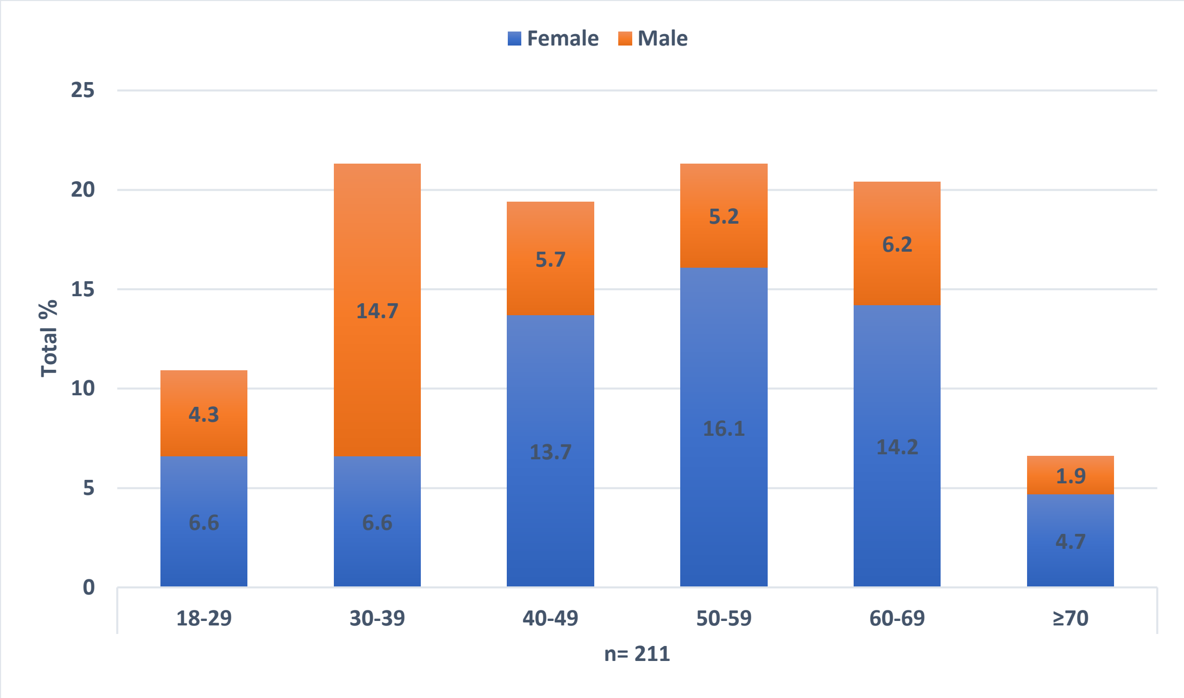

Figure 5.12: Distribution for the primary data sample by sex and age group

5.2.3 Grouping of the primary data FFQ dietary items and their mean frequency of consumption per day

The modified EPIC FFQ used to collect the primary data contained 125 food items. To classify the data into an appropriate number of food types before undertaking PCA, the food items were first grouped based on their main similarities in nutritional profile and culinary practice into the largest possible categories such as grouping the three food items of grilled fish, tuna and shrimp into a single group: Seafood. After that, items that showed very low to no factor loading within the PCA were grouped with similar category food items resulting in the final 28-food group items (Table 5.13). Furthermore, Table 5.13 shows the mean frequency of consumption per day for each of the food items and the mean frequency of consumption per day for the corresponding food groups among the participants.

Table 5.13: The mean frequency of consumption per day of food items and their corresponding food groups

	Ungrouped food items	M	SD		Grouped food items	M	SD
1	Lamb meat	0.22	0.25	1	Red meat	0.46	0.55
2	Cow meat	0.04	0.13				
3	Camel meat	0.04	0.13				
4	Meat kebab	0.05	0.14				
5	Grilled meat	0.06	0.15				
6	Liver dish	0.05	0.13				
7	Chicken	0.38	0.41	2	Chicken	0.63	0.68
8	Grilled chicken	0.12	0.30				
9	Chicken Kebab	0.05	0.13				
10	Shaorma dish	0.07	0.15				
11	Fried chicken	0.12	0.26	3	Fried chicken and fish	0.21	0.35
12	Fried Fish	0.08	0.21				
13	Grilled fish	0.05	0.13	4	Seafood	0.20	0.4
14	Tuna and canned fish	0.12	0.31				
15	Shrimp	0.04	0.19				
16	Sausage	0.01	0.07	5	Processed meat	0.10	0.22
17	Meat burger	0.04	0.11				
18	Chicken burger	0.05	0.12				
19	White rice	0.48	0.50	6	Rice and Macaroni	0.93	0.99
20	Biryani rice	0.25	0.45				
21	Macaroni	0.20	0.43				
22	White bread	0.36	0.67	7	White bread	0.36	0.67
23	Brown bread	0.57	0.77	8	Brown bread	0.57	0.77
24	Pizza (one piece)	0.11	0.30	9	Baked items	0.38	0.88
25	Other baked items	0.15	0.76				
26	Pastry such as croissant	0.12	0.24				
27	Mashed potato	0.06	0.17	10	Non-fried potato	0.14	0.29
28	Baked potato	0.07	0.18				
29	Fried potato	0.12	0.22	11	Fried potato	0.13	0.22

	Ungrouped food items	M	SD		Grouped food items	M	SD
30	Asidah	0.03	0.14	12	Sugary breakfasts	0.16	0.40
31	Ma'sop	0.05	0.21				
32	Breakfast cereals	0.08	0.25				
33	Falafel sandwich	0.07	0.14	13	Sandwiches	0.46	0.59
34	Liver sandwich	0.06	0.16				
35	Meat sandwich	0.04	0.12				
36	Chicken sandwich	0.07	0.21				
37	Shawarma Sandwich	0.07	0.15				
38	Egg sandwich	0.14	0.25				
39	Whole milk (cup)	0.23	0.37	14	Full-fat dairy items	1.46	1.38
40	Full-fat laban	0.24	0.50				
41	Full fat yoghurt	0.24	0.45				
42	Cream cheese	0.21	0.33				
43	White cheese	0.31	0.41				
44	Full-fat labnah	0.13	0.45				
45	Full-fat cream	0.10	0.20				
46	Low-fat milk (cup)	0.14	0.29	15	Low and fat-free dairy items	1.19	1.70
47	Low-fat laban	0.15	0.38				
48	Low-fat yoghurt	0.21	0.43				
49	Fat-free milk (cup)	0.06	0.24				
50	Fat-free laban	0.04	0.17				
51	Fat-free yoghurt	0.12	0.42				
52	Low-fat cheese	0.17	0.40				
53	Low-fat cream	0.07	0.34				
54	Low-fat labnah	0.07	0.19				
55	Fat-free cream	0.04	0.15				
56	Fat-free labnah	0.04	0.15				
57	Butter	0.10	0.34	16	Margarine and butter (teaspoon)	0.19	0.48
58	Margarine	0.08	0.21				
59	Egg (one egg)	0.27	0.51	17	Egg	0.27	0.51

	Ungrouped food items	M	SD		Grouped food items	M	SD
60	Salted biscuit	0.16	0.37	18	Confectionary and other sweets	0.75	1.24
61	Sweet biscuit	0.13	0.33				
62	Cake	0.13	0.31				
63	Ice-cream	0.10	0.24				
64	Chocolate	0.18	0.38				
65	Caramel	0.05	0.20				
66	Crisps	0.12	0.39	19	Crisps	0.12	0.39
67	Nuts such as peanuts	0.12	0.22	20	Nuts	0.12	0.22
68	Canned fruits such as pineapple	0.04	0.13	21	Dried fruits and Pickles	0.30	0.48
69	Dried fruits	0.06	0.17				
70	Pickles	0.13	0.29				
71	Soup (bowl)	0.11	0.38	22	Soup	0.11	0.38
72	Sugar (teaspoon) added to tea or coffee	0.48	1.08	23	Sugar (added to coffee and tea)	0.48	1.08
73	Mayo (one spoon)	0.05	0.16	24	Sauces such as ketchup and mayo	0.33	0.86
74	Sauces (such as ranch or cheese)	0.06	0.21				
75	Ketchup	0.16	0.50				
76	Jam (spoon)	0.06	0.35				
77	Red tea (cup)	1.03	1.21	25	Tea and coffee	3.10	2.98
78	Green tea (cup)	0.70	1.16				
79	Arabic coffee	1.04	1.41				
80	Express coffee as cappuccino	0.30	0.63				
81	Decaf coffee	0.04	0.16				
82	Cocoa	0.07	0.34	26	Cold beverages	0.77	1.73
83	Sugary carbonated drinks	0.23	0.64				
84	Caned fruit drinks	0.11	0.30				
85	Condensed fruit drinks	0.11	0.32				
86	Juices	0.16	0.41				
87	Diet carbonated drinks	0.09	0.40				

	Ungrouped food items	M	SD		Grouped food items	M	SD
88	Date	1.04	1.34	**27**	**Fruits**	**3.03**	**3.39**
89	Pineapple	0.09	0.25				
90	Cantaloupe	0.08	0.17				
91	Watermelon	0.12	0.28				
92	Apricot	0.08	0.19				
93	Apple	0.31	0.59				
94	Pear	0.13	0.22				
95	Mango	0.10	0.19				
96	Grape	0.16	0.29				
97	Orange or mandarin	0.22	0.33				
98	Banana	0.21	0.32				
99	Peach	0.09	0.24				
100	Strawberry	0.07	0.16				
101	Plum	0.18	2.16				
102	Berries	0.06	0.16				
103	Avocado	0.04	0.13				
104	Kiwi	0.06	0.15				

	Ungrouped food items	M	SD		Grouped food items	M	SD
105	Green salad	0.58	0.52	**28**	**Vegetables**	**4.40**	**5.20**
106	Cucumber	0.44	0.54				
107	Spinach	0.08	0.21				
108	Broccoli	0.07	0.24				
109	Cabbage	0.08	0.24				
110	Peas	0.09	0.20				
111	Beans	0.15	0.28				
112	Courgette	0.12	0.23				
113	Cauliflower	0.08	0.42				
114	Shallots	0.11	0.44				
115	Onions	0.30	0.53				
116	Garlic	0.27	0.51				
117	Mushrooms	0.09	0.43				
118	Bell peppers	0.22	0.53				
119	Carrots	0.36	0.91				
120	Lettuce	0.40	0.60				
121	Tomato	0.38	0.46				
122	Lentils	0.15	0.41				
123	Pumpkin	0.17	0.75				
124	Corn	0.14	0.30				
125	Beets	0.10	0.29				

Figure 5.13 also shows the mean frequency of consumption per day of the grouped food items for easier comparison. The food group with the highest frequency per day is vegetables, followed by tea and coffee and fruit.

*****For simplicity, the grouped food items of the primary data will be referred to as only "food items" from this point onwards*****

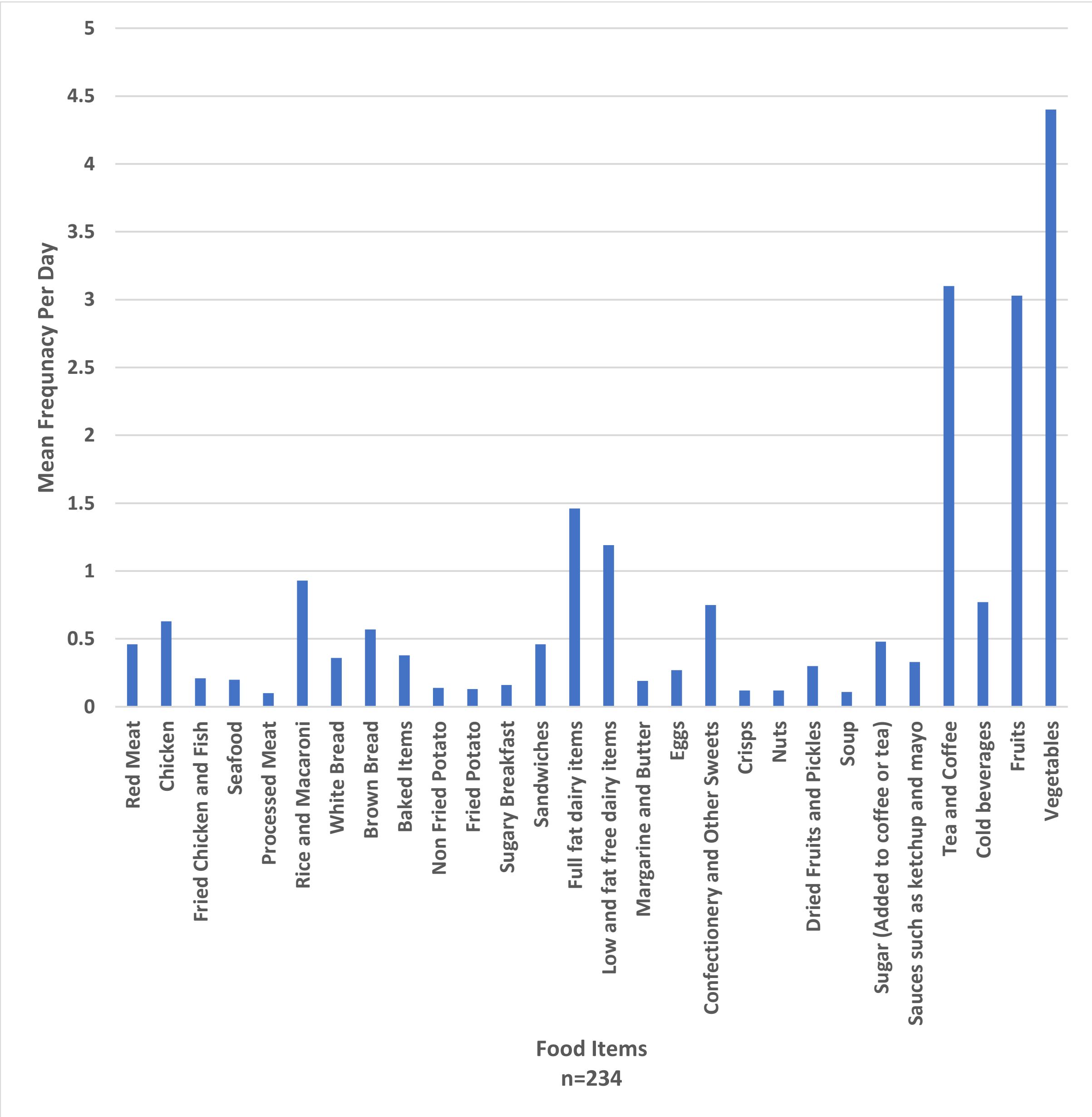

Figure 5.13: Mean frequency of consumption per day of the primary data FFQ food items

5.2.4 Primary data principal Component Analysis and the resulting dietary patterns

To carry out the PCA for the primary data first, Bartlett's test of Sphericity was conducted which resulted in a p-value less than 0.001; thus, it demonstrates that the variable is suitable for structure detection within the factor analysis. To measure the adequacy of sample size for the intended PCA, Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was done resulting in a value of 0.79 indicating that the sample size was both adequate and in the desirable range (101).

Exploratory factor analysis was done to identify the best structure for the dietary patterns. The first step was to do PCA with oblique rotation to identify the correlation matrix which can indicate whether oblique or orthogonal rotation is more appropriate. Direct Oblimin rotation is an oblique rotation that will result in a more accurate factor analysis solution if the components are correlated with each other (102).

However, upon doing PCA with Direct Oblimin rotation, the resulting component correlation matrix showed that there is a very low correlation between the resulting nine components that have an eigenvalue exceeding one. The correlation matrix values shown in Table 5.14 indicate that the components are not suitable for an oblique rotation due to having poorly correlated factors and therefore an orthogonal rotation would result in a more accurate solution.

Table 5.14: Primary data PCA component correlation matrix

Component	1	2	3	4	5	6	7	8	9
1	1	0.137	0.124	0.134	0.16	0.175	0.189	-0.226	0.168
2	0.137	1	0.103	0.078	0.136	0.18	0.223	-0.075	0.103
3	0.124	0.103	1	0.133	0.11	0.116	0.065	-0.203	0.101
4	0.134	0.078	0.133	1	0.094	0.103	0.143	-0.068	-0.053
5	0.16	0.136	0.11	0.094	1	0.1	0.155	-0.177	0.117
6	0.175	0.18	0.116	0.103	0.1	1	0.145	-0.157	0.12
7	0.189	0.223	0.065	0.143	0.155	0.145	1	-0.077	0.048
8	-0.226	-0.075	-0.203	-0.068	-0.177	-0.157	-0.077	1	-0.201
9	0.168	0.103	0.101	-0.053	0.117	0.12	0.048	-0.201	1

Extraction Method: Principal Component Analysis, Rotation Method: Oblimin with Kaiser Normalization

To generate the best solution from PCA, the analysis was done multiple times with nine, seven, five, four and three-factor solutions. No food items within the patterns had less than 0.1 loadings in all resulting patterns and therefore no food items have been removed to find the best solution (88). The best PCA structure with the best interpretability using the varimax rotation with the highest variance explained and the highest eigenvalue was obtained from retaining a five-factor solution which explains 55% of the variation within the data. Each of the five factors has at least 5% of the variance explained and an eigenvalue exceeding 1.58 (Figure 6.14).

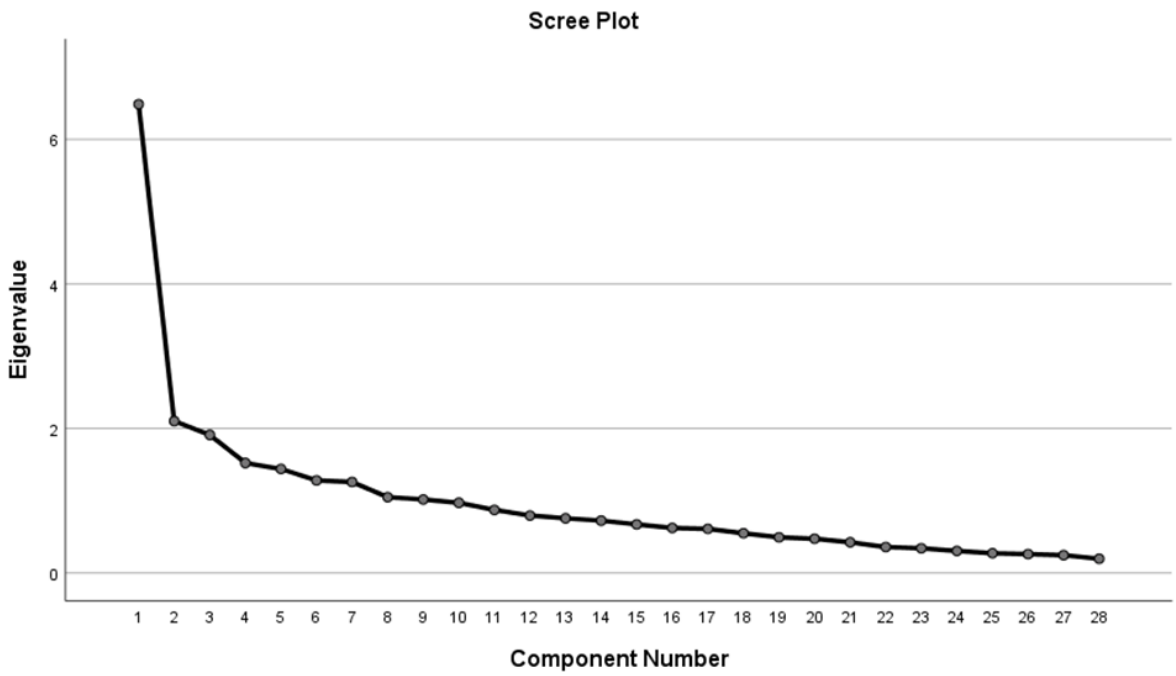

Figure 6.14: A scree plot showing the eigenvalue of the resulting components from PCA using varimax rotation

To easily distinguish between the identified dietary patterns, they are named according to the main dietary elements that distinguish them from each other: Comprehensive, Traditional, Fast Food, Snacking and Low Processed Food (Table 5.15).

Table 5.15: The result of primary data PCA with varimax rotation at a fixed number of factors of five

	1 Comprehensive	2 Traditional	3 Fast Food	4 Snacking	5 Low processed Food
Red Meat	**-**	**-**	**-**	**-**	**0.623**
Chicken	**-**	**0.340**	**0.458**		**-**
Fried Chicken and Fish	**0.617**	**-**	**-**	**-**	**-**
Seafood	**0.705**	**-**	**-**	**-**	**-**
Processed Meat	**-**	**-**	**0.411**	**0.450**	**-**
Rice and Macaroni	**-**	**0.705**	**-**	**-**	**-**
White Bread	**-**	**-**	**0.677**	**-**	**-**
Brown Bread	**-**	**0.366**	**-**	**-**	**-**
Baked Items	**-**	**-**	**0.410**	**0.321**	**-**
Non Fried Potato	**0.545**	**-**	**-**	**-**	**0.372**
Fried Potato	**-**	**-**	**0.512**	**-**	**-**
Sugary Breakfast	**0.529**	**-**	**0.372**	**-**	**-**
Sandwiches	**0.473**	**0.427**	**-**	**-**	**-**
Full Fat Dairy Items	**-**	**0.543**	**-**	**-**	**-**
Low and Fat Free Dairy Items	**-**	**-**	**-**	**-**	**0.486**
Margarine and Butter	**0.786**	**-**	**-**	**-**	**-**
Eggs	**0.815**	**-**	**-**	**-**	**-**
Confectionery and Other Sweets	**-**	**-**	**-**	**0.594**	**-**
Crisps	**-**	**-**	**-**	**0.687**	**-**
Nuts		**0.334**	**-**	**0.557**	**-**
Dried Fruits and Pickles	**0.344**	**0.303**	**-**	**-**	**-**
Soup	**-**	**0.618**	**-**	**0.303**	**-**
Sugar (Added to Coffee or Tea)	**-**	**0.490**	**-**	**-**	**-**
Sauces such as Ketchup and Mayo	**0.392**	**-**	**-**	**0.512**	**-**
Tea and Coffee	**-**	**0.431**	**-**	**-**	**-**
Cold Beverages	**-**	**-**	**0.478**	**-**	**0.518**
Fruits	**0.342**	**0.581**	**-**	**-**	**-**
Vegetables	**0.796**	**-**	**-**	**-**	**-**

*Only values above 0.3 are showing

The resulting loading factors for each dietary pattern were used to calculate the dietary pattern scores by multiplying the loading for each dietary item within the identified dietary patterns by the means for daily consumption of food items for the same food items for each participant and when the multiplied values added together would result in the dietary pattern score for that individual. Each participant has a dietary pattern score for each of the dietary patterns whereby the higher the dietary score, the higher the participant's adherence to that pattern. The mean values for the dietary pattern scores for the total primary data sample can be seen in Figure 5.15 and Table 5.16. Figure 5.15 and Table 5.16 show that the dietary pattern with the most adherence within the primary data sample is the Comprehensive dietary pattern, followed by Traditional, Fast food, Low processed foods and lastly the Snacking dietary pattern.

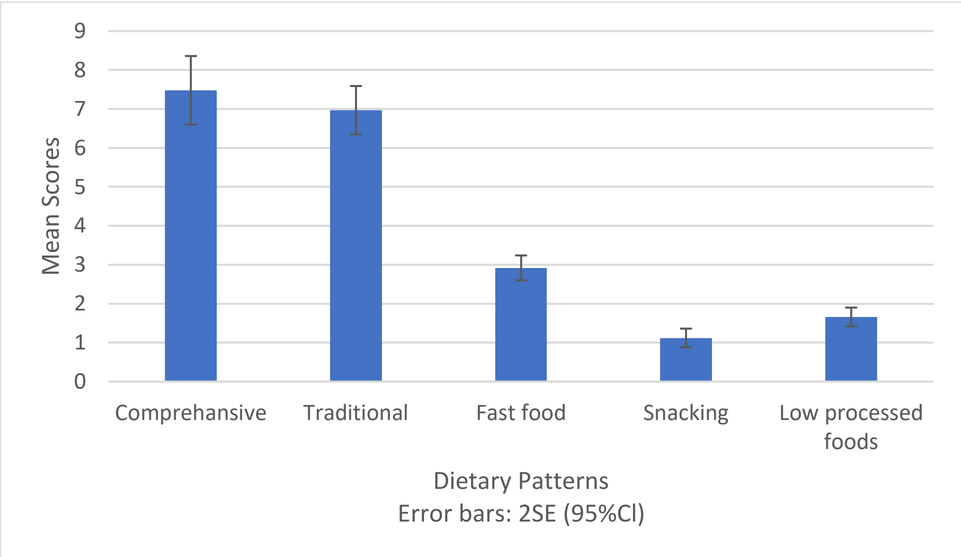

Figure 5.15: Primary data mean dietary pattern scores

Table 5.16: Primary data mean dietary pattern scores with standard deviations

Dietary Patterns	M	SD
Comprehensive	7.48	6.71
Traditional	6.97	4.82
Fast Food	2.92	2.39
Snacking	1.12	1.8
Low Processed Food	1.66	1.79

5.2.5 Age groups association with the primary data dietary patterns

The distribution of the mean dietary pattern scores by age group shows that the Comprehensive dietary pattern scores are highest among the age group 60-69 years, followed by the age group 40-49 years. The Traditional pattern appears to have its highest scores in the middle age group from 40 to 59 years. In contrast, the Fast Food, Snacking and Low Processed Food patterns have their highest scores in the youngest age group, 18-29 years (Figure 5.16 and Table 5.17).

On examining the relationship between age and dietary pattern scores using linear regression hypothesis test, both the Fast Food and Snacking dietary patterns are found to be significantly (p-value= 0.019 and 0.009 respectively) and negatively associated with age (*b*= -0.162 and -0.180 respectively) (Table 5.17).

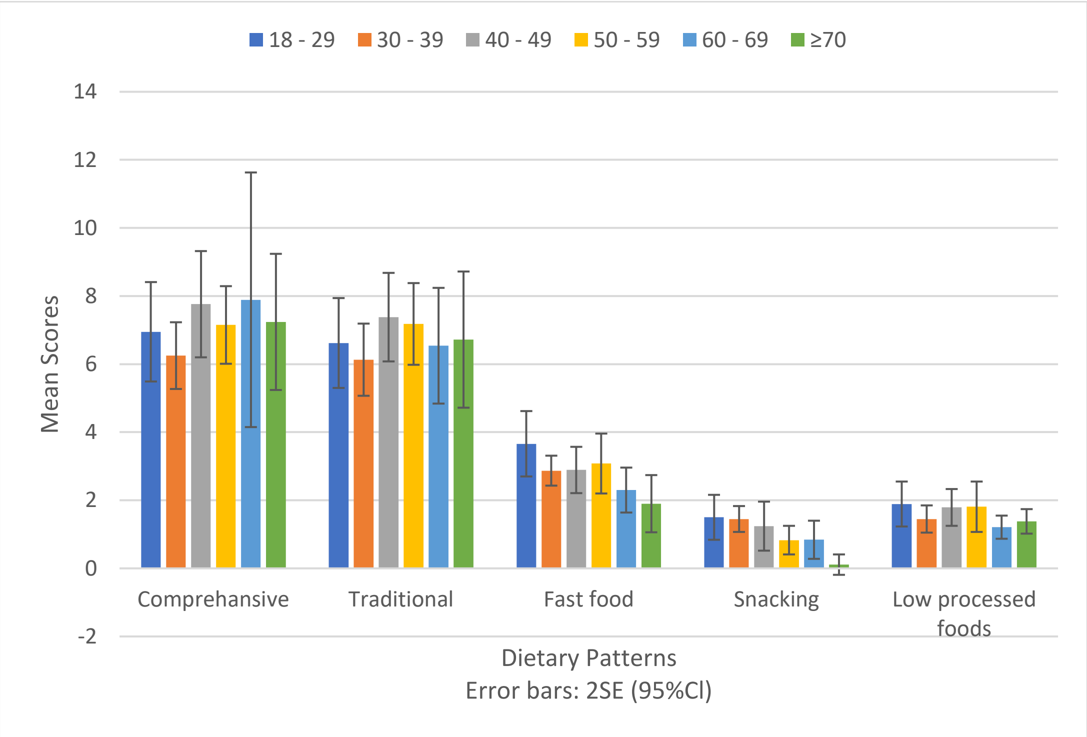

Figure 5.16: Primary data mean dietary pattern scores stratified by age group

Table 5.17: Primary data dietary pattern score mean, standard deviation and linear regression results while stratified by age group

	18 - 29		**30 - 39**		**40 - 49**		**50 - 59**		**60 - 69**		**≥70**		
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**Age *b* (p-value)**
Comprehensive	6.95	3.48	6.25	3.26	7.76	5.02	7.15	3.82	7.89	12.24	7.24	3.74	0.072 (0.298)
Traditional	6.62	3.18	6.13	3.57	7.38	4.15	7.18	4.03	6.54	5.6	6.72	3.74	0.040 (0.561)
Fast Food	3.66	2.32	2.87	1.45	2.89	2.19	3.08	2.94	2.3	2.14	1.9	1.57	**-0.162 (0.019)**
Snacking	1.5	1.58	1.45	1.28	1.24	2.32	0.83	1.41	0.84	1.82	0.11	0.58	**-0.180 (0.009)**
Low Processed Food	1.89	1.6	1.45	1.32	1.79	1.71	1.81	2.5	1.21	1.09	1.38	0.67	-0.066 (0.343)

5.2.6 Sex association with the primary data dietary patterns

While examining the relationship between primary data dietary pattern scores and sex, it is found that females scored higher for the Comprehensive and Traditional dietary patterns compared to males. In contrast, the males scored higher for the Fast Food, Snacking and Low Processed Food dietary patterns in comparison to females (Figure 5.17 and Table 5.18).

After adjusting for age, it is found that being male was associated with the Low Processed Food pattern (OR= 1.208, 95%CI= 1.007-1.450). All other associations between sex and dietary pattern scores were insignificant before and after being adjusted for age (Table 5.18).

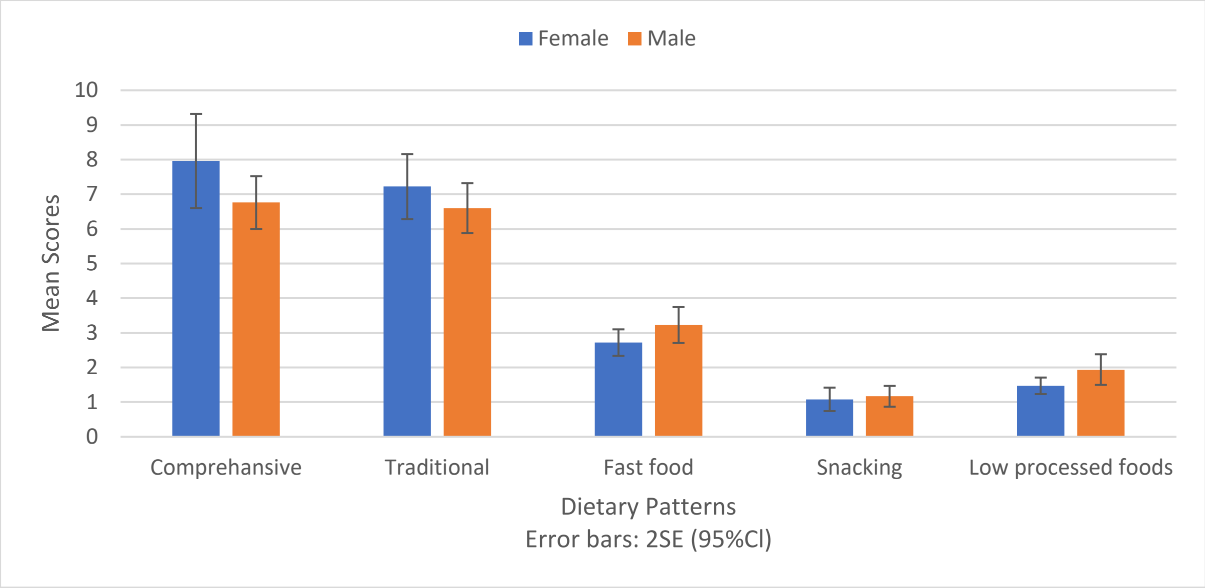

Figure 5.17: Primary data mean dietary pattern scores stratified by sex

Table 5.18: Primary data dietary pattern score mean, standard deviation and odds ratio results while stratified by sex

	Female		**Male**		**OR (95%CI) of being Male**	
	M	**SD**	**M**	**SD**	**Model 1***	**Model 2****
Comprehensive	7.96	8.1	6.76	3.7	0.964 (0.912-1.019)	0.954 (0.887-1.027)
Traditional	7.22	5.55	6.6	3.45	0.972 (0.917-1.031)	0.985 (0.917-1.057)
Fast Food	2.72	2.27	3.23	2.55	1.093 (0.978-1.221)	1.099 (0.967-1.250)
Snacking	1.08	2.02	1.17	1.44	1.030 (0.892-1.189)	1.020 (0.861-1.208)
Low Processed Food	1.47	1.48	1.94	2.16	1.157 (0.992-1.351)	**1.208 (1.007-1.450)**

* Unadjusted, **Adjusted to Age

5.2.7 Diagnosis groups association with the primary data dietary patterns

On exploring the relationship between primary data dietary pattern scores and the diagnosis groups, the non-diabetics scored highest for the Snacking dietary pattern in comparison with other groups. This is expected since the Snacking dietary pattern was more common in the young age groups where having a diagnosis of T2D is less common. Those diagnosed with T2D scored highest for the Comprehensive dietary pattern while the undiagnosed diabetics scored higher in the Traditional, Fast Food and Low Processed Food dietary patterns in comparison with the other groups (Figure 5.18 and Table 5.19).

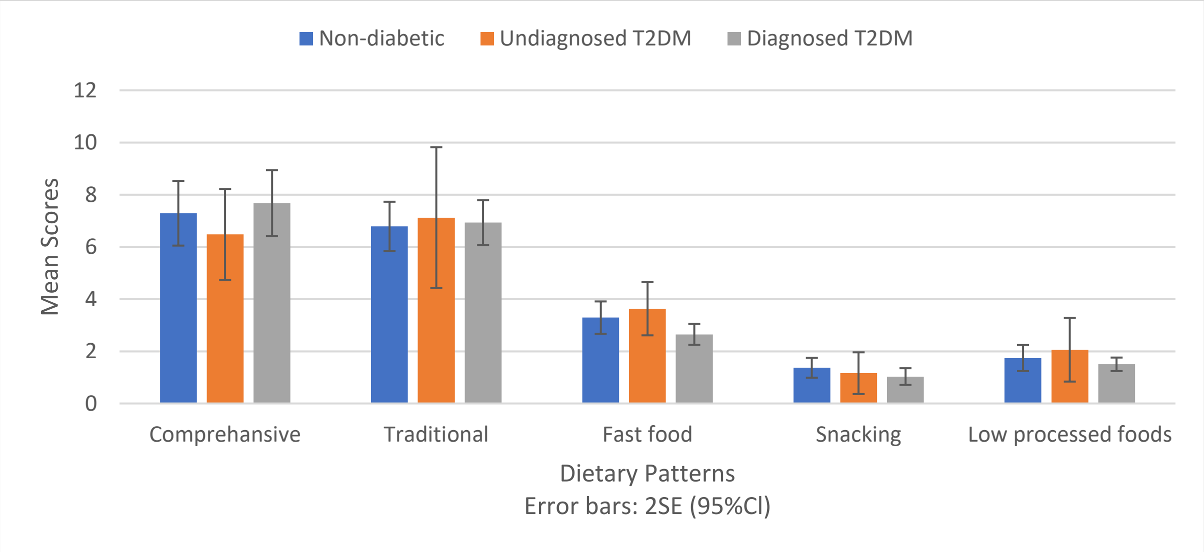

Figure 5.18: Primary data mean dietary pattern scores stratified by diagnosis group

Table 5.19: Primary data dietary pattern score means and standard deviations stratified by diagnosis group

	Diagnosis group					
	Non-diabetic		Undiagnosed T2D		Diagnosed T2D	
	M	SD	M	SD	M	SD
Comprehensive	7.29	4.82	6.48	3.15	7.68	7.71
Traditional	6.79	3.67	7.12	4.87	6.93	5.3
Fast Food	3.29	2.41	3.63	1.82	2.65	2.43
Snacking	1.37	1.44	1.16	1.43	1.03	1.96
Low Processed Food	1.74	1.9	2.06	2.2	1.5	1.64

On examining the OR of being T2D, it is found that participants who scored higher in the Fast Food dietary pattern had lower odds of being diagnosed with T2D (OR=0.889, 95%Cl=0.793-0.998). This was expected since Fast Food was significantly associated with lower age groups and hence, this significant relationship is lost after adjusting for age and sex (Table 5.20). In contrast, after adjusting for age and sex, it is found that participants who scored higher in the low processed food dietary pattern had higher odds of being diagnosed with T2D (OR=1.162, 95%CI=1.115-1.212). After adjusting for having a family history of T2D, smoking status and exercising regularly, this finding is no longer statistically significant. There were no significant relationships between the dietary pattern scores and the OR of having undiagnosed T2D before and after adjusting for age and sex (Table 5.20).

Table 5.20: Primary data dietary pattern score hypothesis tests for the in-between differences and association with the diagnosis groups

	OR of being T2D (95%Cl)			**OR of being undiagnosed diabetic (95%Cl)**		
	Model 1[1]	**Model 2[2]**	**Model 3[3]**	**Model 1[1]**	**Model 2[2]**	**Model 3[3]**
Comprehensive	1.013 (0.967-1.062)	0.985 (0.889-1.090)	0.982 (0.871-1.107)	0.956 (0.823-1.111)	0.944 (0.792-1.127)	0.936 (0.781-1.122)
Traditional	1.004 (0.947-1.064)	0.949 (0.844-1.066)	0.946 (0.838-1.067)	1.022 (0.879-1.189)	1.003 (0.854-1.190)	0.993 (0.833-1.185)
Fast Food	**0.889 (0.793-0.998)**	0.9812 (0.819-1.175)	0.728 (0.967-0.803)	1.063 (0.830-1.361)	1.129 (0.818-1.558)	1.149 (0.813-1.623)
Snacking	0.915 (0.788-1.063)	1.078 (0.806-1.442)	1.055 (0.787-1.413)	0.887 (0.549-1.432)	1.057 (0.620-1.804)	1.077 (0.622-1.865)
Low Processed Food	0.913 (0.782-1.066)	**1.162 (1.115-1.212)**	1.031 (0.792-1.344)	1.081 (0.815-1.432)	1.056 (0.683-1.632)	1.009 (0.614-1.656)

[1]Unadjusted, [2]Adjusted to age and sex, [3]Adjusted to age, sex, having a family history of T2D, smoking status and exercising regularly

5.2.8 HbA1c levels association with the primary data dietary patterns

The distribution of the dietary pattern scores among HbA1c levels shows that those with diabetic levels of HbA1c scored highest in the Comprehensive and Traditional dietary patterns compared to the other levels of HbA1c. Those with normal levels of HbA1c scored highest in the Fast Food, Snacking and Low processed food dietary patterns, which is expected given that Fast Food and Snacking is more common among the young (Figure 5.22 and Table 5.21).

By examining the relationship between dietary pattern scores and HbA1c levels using linear regression, the Comprehensive and Traditional dietary patterns are found to be positively associated with HbA1c levels [*b* (b-value) = 0.164 (0.016) and 0.165 (0.015) respectively]. However, this association is lost after adjusting for age and sex (Table 5.24). In contrast, the Fast Food and Snacking dietary patterns show a positive association with HbA1c levels after adjusting for age and sex [*b* (b-value) = 0.182 (0.007) and 0.205 (0.002) respectively] which also continued to be significant after adjusting for having a family history of T2D, smoking status and exercising regularly. This suggests that after controlling for age (given that most of those diagnosed with T2D are older), both the Fast Food and Snacking dietary patterns are significantly associated with having high levels of HbA1c. The interpretation of the relationship between HbA1c levels and the dietary pattern scores could be complicated by those diagnosed with T2D also being on glucose controlling medications. Therefore, the next section shows the results of the same analysis after excluding those with diagnosed T2D.

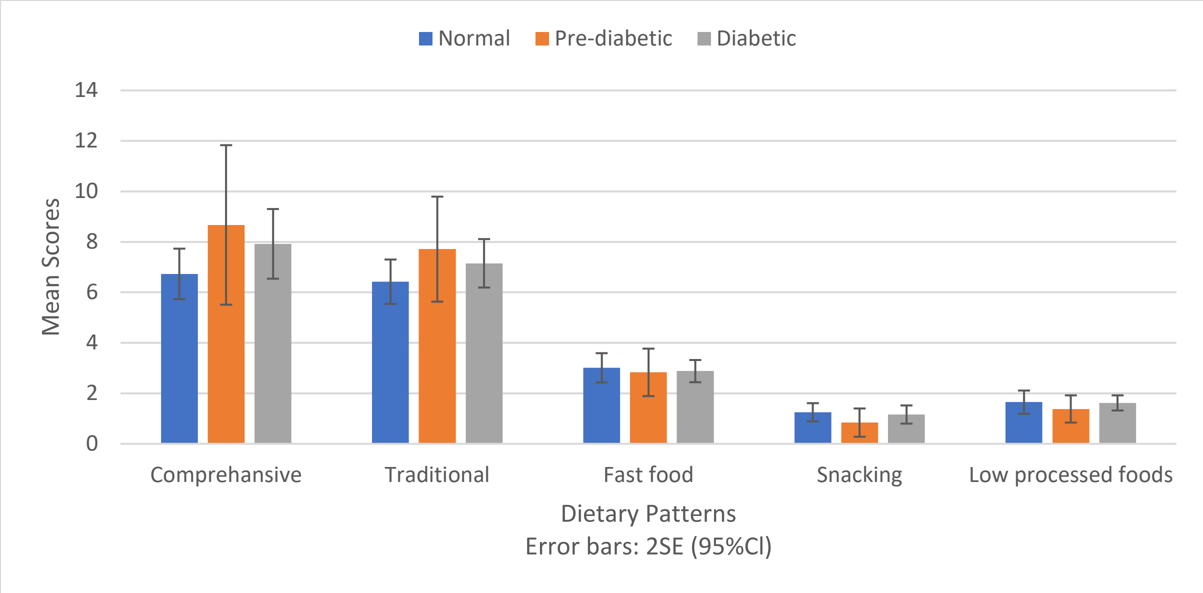

Figure 5.19: Primary data mean dietary pattern scores stratified by HbA1c level

Table 5.21: Primary data dietary pattern score mean, standard deviation and linear regression results stratified by HbA1c level

	Normal		Pre-diabetic		Diabetic		***b* (p-value)**		
	M	**SD**	**M**	**SD**	**M**	**SD**	**Model 1[1]**	**Model 2[2]**	**Model 3[3]**
Comprehensive	6.73	3.97	8.67	6.31	7.92	8.02	**0.164 (0.016)**	0.108 (0.108)	0.065 (0.332)
Traditional	6.42	3.5	7.71	4.16	7.15	5.52	**0.165 (0.015)**	0.087 (0.196)	0.046 (0.497)
Fast Food	3.01	2.34	2.83	1.89	2.88	2.55	0.099 (0.149)	**0.182 (0.007)**	**0.147 (0.032)**
Snacking	1.25	1.43	0.84	1.11	1.16	2.07	0.099 (0.149)	**0.205 (0.002)**	**0.181 (0.008)**
Low Processed Food	1.65	1.85	1.38	1.09	1.62	1.79	0.007 (0.913)	0.046 (0.499)	0.048 (0.493)

[1]Unadjusted, [2]Adjusted to age and sex, [3]Adjusted to age, sex, having a family history of T2D, smoking status and exercising regularly

5.2.9 HbA1c levels excluding those diagnosed with T2D association with the primary data dietary patterns

While excluding those diagnosed with T2D who are on glucose controlling medication, the distribution of the dietary pattern scores by HbA1c level shows that this time, those with pre-diabetic levels of HbA1c scored highest in the Comprehensive and Traditional dietary patterns compared to the other levels of HbA1c. Those with normal levels of HbA1c still scored highest in the Snacking dietary pattern while those with diabetic levels of HbA1c scored highest in the Fast Food and Low Processed food dietary patterns (Figure 5.20 and Table 5.22).

By examining the relationship between dietary pattern scores and HbA1c levels using linear regression (after excluding those diagnosed with T2D), there were no statistically significant relationships found between HbA1c levels and any of the dietary pattern scores while both adjusting and not adjusting for age and sex (Table 5.22).

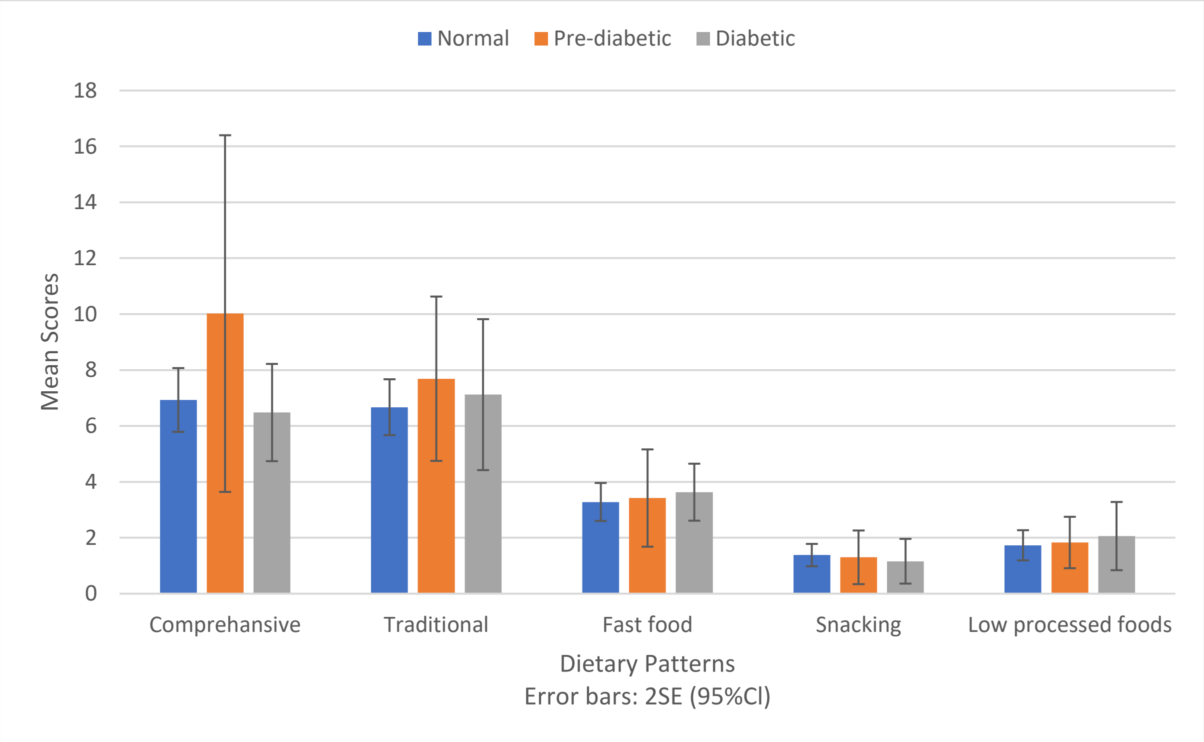

Figure 5.20: Primary data mean dietary pattern scores stratified by HbA1c level after excluding those diagnosed with T2D

Table 5.22: Primary data dietary pattern score mean, standard deviation and linear regression results stratified by HbA1c level after excluding those diagnosed with T2D

	Normal		**Pre-diabetic**		**Diabetic**		***b* (p-value)**		
	M	**SD**	**M**	**SD**	**M**	**SD**	**Model 1[1]**	**Model 2[2]**	**Model 3[3]**
Comprehensive	6.93	4.12	10.02	8.44	6.48	3.15	0.013 (0.911)	-0.029 (0.831)	-0.018 (0.899)
Traditional	6.67	3.66	7.69	3.89	7.12	4.87	0.015 (0.898)	-0.034 (0.794)	-0.024 (0.864)
Fast Food	3.28	2.45	3.42	2.3	3.63	1.82	0.072 (0.544)	0.064 (0.625)	0.082 (0.553)
Snacking	1.38	1.47	1.3	1.27	1.16	1.43	-0.012 (0.922)	0.004 (0.974)	0.015 (0.912)
Low Processed Food	1.73	1.98	1.83	1.23	2.06	2.2	0.057 (0.631)	-0.024 (0.859)	-0.015 (0.918)

[1]Unadjusted, [2]Adjusted to age and sex, [3]Adjusted to age, sex, having a family history of T2D, smoking status and exercising regularly

5.2.10 Body Mass Index association with the primary data dietary patterns

On examining the distribution of the dietary pattern scores by BMI, those with obese levels of BMI (>30 kg/m^2) scored highest in the Comprehensive, Traditional and Fast Food dietary patterns. Those who are underweight scored highest in the Low Processed Food while avoiding food items that are common in the Snacking dietary pattern (Figure 5.21 and Table 5.23).

While examining the relationship between BMI level and dietary pattern scores using linear regression, both the Comprehensive and Traditional dietary patterns were positively associated with BMI [*b*(p-value) = 0.160 (0.015) and 0.152 (0.021) respectively]. This association is lost after adjusting for age and sex for the Traditional pattern (suggesting that it is indeed common among the older age groups) but it continues to be significant for the Comprehensive (*b* (p-value) =0.140 (0.044)) but lost as well after controlling for smoking status and exercising regularly. This suggests that unlike the Traditional pattern, the Comprehensive pattern might be common among those with high BMI levels across both sexes and different age groups. After adjusting for both age and sex, there is a significant association between BMI and the

Snacking dietary pattern scores (*b* (p-value) = 0.153 (0.030)) which also continues to be present after controlling for smoking status and exercising regularly (Table 5.23).

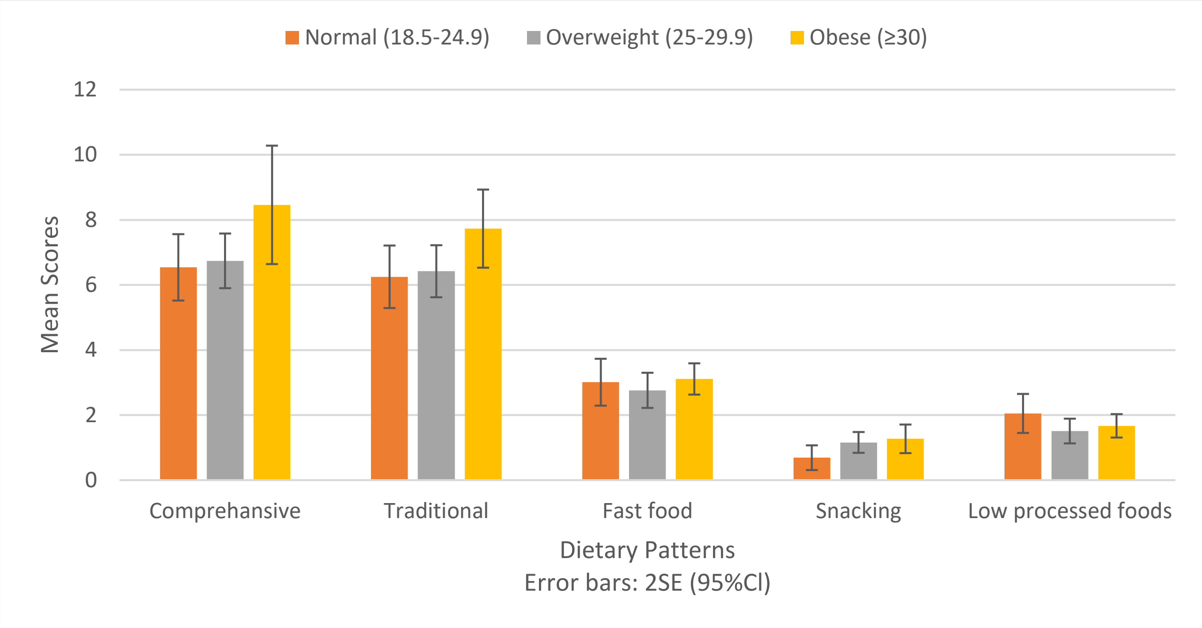

Figure 5.21: Primary data mean dietary pattern scores stratified by BMI level

Table 5.23: Primary data dietary pattern score mean, standard deviation and linear regression results stratified by BMI level

	Normal (18.5-24.9)		Overweight (25-29.9)		Obese (≥30)		*b* (p-value)		
	M	**SD**	**M**	**SD**	**M**	**SD**	**Model 1[1]**	**Model 2[2]**	**Model 3[3]**
Comprehensive	6.54	3.08	6.74	4.04	8.46	9.18	**0.160 (0.015)**	**0.140 (0.044)**	0.132 (0.057)
Traditional	6.25	2.87	6.42	3.83	7.73	6.06	**0.152 (0.021)**	1.113 (0.103)	0.112 (0.104)
Fast Food	3.01	2.17	2.76	2.56	3.11	2.37	0.087 (0.186)	0.107 (0.131)	0.109 (0.121)
Snacking	0.69	1.15	1.16	1.53	1.27	2.2	0.107 (0.106)	**0.153 (0.030)**	**0.142 (0.044)**
Low Processed Food	2.05	1.82	1.51	1.79	1.67	1.82	0.005 (0.945)	-0.067 (0.344)	-0.125 (0.079)

[1]Unadjusted, [2]Adjusted for age and sex, [3]Adjusted for age, sex, smoking status and exercising regularly

5.2.11 Section two summary

Five dietary patterns were identified within the primary data sample using the modified EPIC FFQ. The five patterns were labelled according to some of their features as Comprehensive, Traditional, Fast Food, Snacking and Low Processed foods dietary patterns (Figure 5.22).

The Comprehensive dietary pattern was positively associated with higher BMI values both before and after adjusting for age and sex (*b*=0.140, p-value=0.030). No other significant association was found for the Comprehensive dietary pattern after adjusting for age and sex. The absence of having a significant association of the comprehensive dietary pattern with age my suggest that this dietary pattern is equally common among all age groups.

The Traditional dietary pattern had no statistically significant association with demographic and health characteristics included in this analysis after adjusting for age and sex. As with the comprehensive dietary pattern, the absence of having significant association with age may suggest that this dietary patter is equally common among all age groups.

The Fast Food dietary pattern was found to be negatively associated with age **(***b*=-0.162, p-value=019). It was also found to be positively associated with higher levels of HbA1c after adjusting for age and sex (*b*=0.182, p-value=0.007). However, the association with HbA1c becomes insignificant after excluding participants with a T2D diagnosis (p-value=0.625).

The Snacking dietary pattern was found to be negatively associated with age (*p*=-0.180, p-value=0.009). It was also found to be positively associated with higher levels of HbA1c after adjusting for age and sex (*b*=0.205, p-value=0.002). However, the association with HbA1c becomes insignificant after excluding participants with a T2D diagnosis (p-value=0.974). The Snacking dietary pattern was also positively associated with higher BMI values after adjusting for age and sex (*b*=0.153, p-value=0.030).

The Low Processed food dietary patterns were more common among males (OR= 1.208, 95%CI= 1.007-1.450). It was also more common among participants with a T2D diagnosis after controlling for age and sex (OR=1.162, 95%CI=1.115-1.212).

Highlighted findings from appendix 5 which contains additional analyses of the primary data show that the low processed food dietary pattern is more common among smokers than non-smokers after adjusting for age and sex (OR=1.325 95%CI=1.045-1.679). There were multiple variations regarding the distribution of the FFQ food items by demographic and health variables. Notably, younger age groups consumed more fizzy drinks while females reported consuming more fruits and vegetables than males.

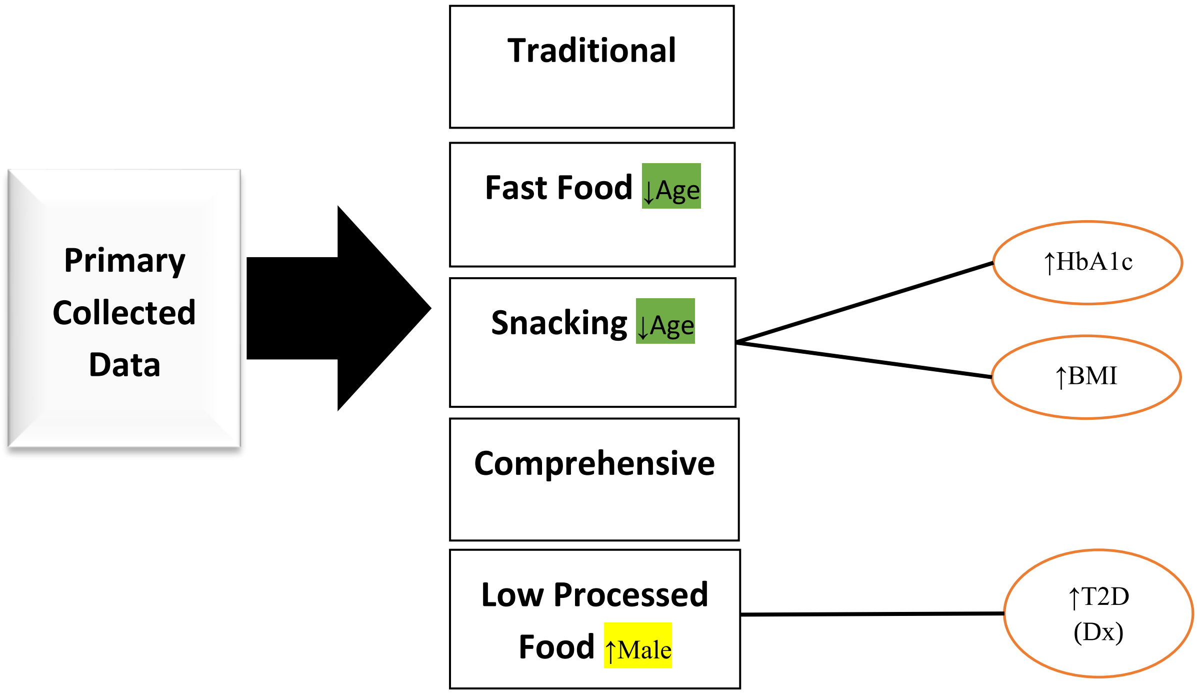

Figure 5.22: Summary of key associations between the primary data dietary patterns and T2D, HbA1c and BMI levels and age (Dx: diagnosed)

Section Three: Comparison between the SHIS data and the primary data

After analysing both the secondary obtained SHIS data and the primary collected data in section 1 and 2 respectively, this section will be concerned with discussing similarities and differences between both data sets. First, a comparison of the study samples will be done. After that, the similarities and differences of the dietary analysis results will be discussed.

5.3.1 Study sample types and differences

Different methods of recruitment were used to recruit the primary and secondary data sample. While the secondary data study sample was recruited from all regions of Saudi Arabia using the process of random selection to ensure a representative sample, the primary data study sample was a convenience sample recruited from the clinical population in the City of Medina in Saudi Arabia. Also, being a small-scale study in comparison to the SHIS, the choice of a clinical population was mainly due to two factors. First, finding associations between diet and T2D was the main focus of this research and it is more feasible to recruit diabetic patients from the general practitioner clinic than to search for them among the general population. The second reason for using a clinic population was to save costs and also to avoid invasive procedures by acquiring HbA1c results from participants' medical records if this had been carried out within the last 3 months before attempting to acquire the blood samples needed for HbA1c.

Being recruited from a clinical population, the primary data study sample is much older than the secondary sample. The primary data sample also had a higher proportion of female respondents. Having different age and sex distributions for the primary and secondary data study samples explains many of the differences in the distribution for other variables such as physical activity and BMI for the primary and secondary study sample. Also, recruiting from a clinical population explains why a history of T2D and chronic diseases other than T2D is more common among the participants in the primary data study sample compared to the secondary data study sample.

The difference in smoking status between the primary and secondary data study sample can be attributed to the primary study sample being older with a higher proportion of participants being diagnosed with T2D. As is evident from the analysis of the secondary data sample, smoking prevalence was higher among the diabetics compared to non-diabetics. Also, the primary data sample was recruited from a clinic population whose smoking might contribute to more adverse health outcomes.

The primary data sample has a higher proportion of those diagnosed with T2D. Therefore, the primary data sample can be seen as more representative of the diabetic population rather than the general population in Saudi Arabia. This can also be seen in the similarities in the demographic and socioeconomic characteristics of the primary data sample and the diagnosed T2D participants in the secondary data sample.

Similarities between the primary data sample and diagnosed T2D participants in the secondary data sample can be seen in many of the socioeconomic and health characteristics. As in the primary data study sample, the T2D group in the secondary data is older with higher BMI. As for the primary data study sample, the secondary data T2D participants have a higher prevalence of smoking and chronic heart disease and exercise less than non-diabetic patients. As self-reported in the primary data study sample, the secondary data T2D participants have a lower level of education, lower employment and lower level of estimated income than the other groups. This indicates how the primary data study sample is more representative of the diabetic population in Saudi Arabia rather than the population as a whole.

5.3.2 The dietary patterns identified in the Saudi population

Using the same method of PCA for both primary and secondary data, different sets of dietary patterns for each of the data sets were identified. The secondary data PCA using 18 broad categories of food items identified four dietary patterns which are Traditional, Dairy Products, Seafood and Fast Food. In comparison, the primary data factor analysis using 125 food items and more detailed FFQ identified five dietary patterns, which are Comprehensive, Traditional, Fast Food, Snacking, and Low Processed Food dietary patterns.

Although having two different sets of dietary patterns is expected given that each data set used a completely different FFQ, there is a considerable degree of similarity and overlap between the dietary patterns for each of the data sets (Figure 5.23). For example, the secondary data Traditional and secondary data Dairy Products dietary patterns overlap with the primary data Comprehensive food pattern in the food items for fruit, vegetables and eggs. Meanwhile, the secondary data Dairy Products dietary pattern and the primary data Traditional dietary pattern both feature dairy items (such as milk) while the secondary data Traditional and the primary data Traditional overlaps in fruits and poultry.

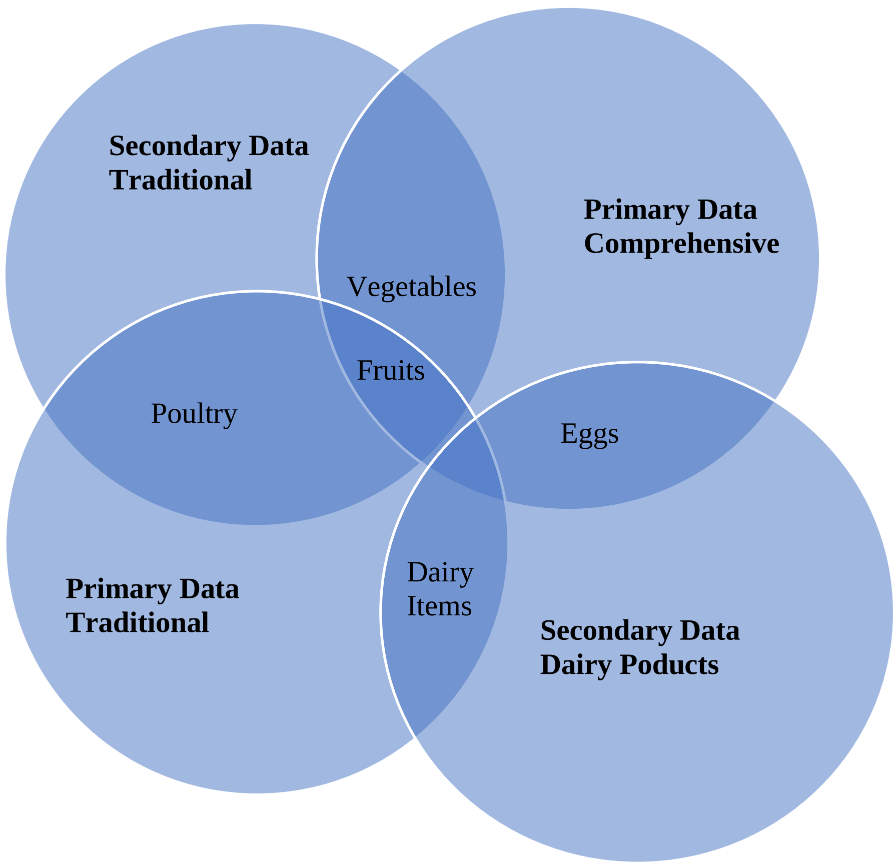

Figure 5.23: The overlap between the secondary data Traditional and Dairy Products dietary patterns and the primary data Comprehensive and Traditional dietary patterns

Furthermore, the food items for the secondary data Fast Food dietary pattern overlap with the primary data Fast Food dietary pattern; both contain processed foods and carbonated drinks (carbonated drinks are included within the cold beverages in the primary data grouped food items). As mentioned before, the SNHS FFQ did not distinguish sugary from non-added sugar carbonated drinks. Also, the secondary data Fast Food dietary pattern overlaps with the primary data Snacking dietary pattern in both including nuts (Figure 5.24). The same associations between age and sex for the secondary data Fast Food dietary pattern can be found for both the primary data Fast Food and Snacking dietary pattern suggesting that they are overlapping patterns, as they are both more common in younger and male population groups.

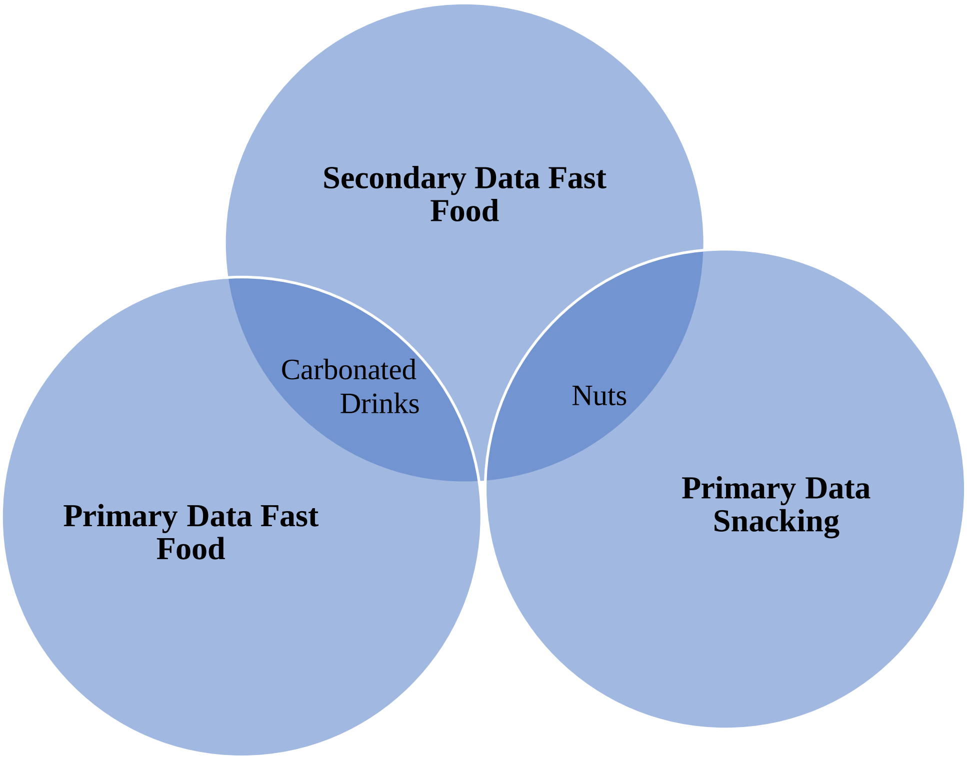

Figure 5.24: The overlap between the secondary data Fast Food dietary pattern and the primary data Fast Food and Snacking dietary patterns

Differences between the dietary patterns identified for both the primary and secondary data can be attributed largely to the differences in the food item numbers and categories within each data set FFQ. The primary data had a more detailed FFQ (Appendix 2) than the secondary data (SHIS) FFQ. The difference was not only in the numbers of items asked about but also in the level of detail for each food category. For example, the secondary data FFQ asked participants about their consumption of processed foods while the primary data FFQ asked participants about the subcategories of processed food such as different types of burgers and sausages.

In comparison, for the food item categories for the secondary data FFQ, there are only 18 food items. The food items in this FFQ are mostly broad categories that are not detailed and also not inclusive of all food categories; for example, the categories of rice and sweets are missing and there is no distinction between low and full-fat dairy items. The reason for that might be that the SHIS was more focused on studying the consumption of specific individual food items rather than dietary patterns and their associations with health and disease. More detailed comparison of the primary and secondary data FFQ food items will be discussed in Section 5.3.6.

5.3.3 Dietary differences among age groups

Overall, both the primary data and the secondary data Traditional dietary patterns did not show any significant association with age, thus, suggesting that the Traditional dietary pattern is common across all age groups. By contrast, the secondary data Fast Food dietary pattern showed a negative association with age, as did the Fast Food and Snacking dietary patterns in the primary data, suggesting that they are more common among young age groups.

5.3.4 Dietary differences by sex

Regarding sex, the primary data Low Processed Food dietary pattern and the secondary data Traditional and both the primary and secondary data Fast Food dietary patterns had a significant association with being male. The other dietary patterns did not have enough evidence to conclude an association with either sex. Fast Food consumption differences among sex will be discussed in greater details in the following chapter.

5.3.5 Dietary differences by smoking status, physical activity and having a history of chronic diseases

As mentioned earlier in this chapter, the differences in the mean dietary scores between the primary and secondary data study sample for smoking status and physical activity could be attributed to differences in the distribution of age, sex and the primary data being mainly from an urban population. Also, the differences in mean dietary scores between the primary and secondary data study samples for having a previous history of chronic disease other than T2D can be attributed to the primary data being collected mainly from a clinical population.

5.3.6 Primary data FFQ food items vs secondary data FFQ food items

The food items used in the secondary data FFQ were broad categories that were also lacking detailed information on specific food items that can be specifically linked to participants' blood glucose levels such as sweets and biscuits. Also, items that have been found in previous studies to be linked to T2D, such as white rice, were not mentioned in the secondary data FFQ. As mentioned before, this is probably because the SHIS was designed to be more concerned with exploring the association of specific food items and a broad category of diseases such as chronic heart disease (46).

However, making a comparison between the primary data and the SHIS in food item frequency is important to ensure the representation of the primary data to the Saudi population. Nevertheless, having different items in each FFQ of the primary and secondary data makes the comparison more difficult. Therefore, it was informative to combine some of the food items from the more detailed primary FFQ to represent food items from the less detailed secondary data FFQ. This enabled comparison of the food items in the primary data FFQ to the secondary data FFQ.

Table 5.24 shows the food items from the primary data FFQ that have been combined in categories that would represent those from the secondary data FFQ. Only 71/125 food items from the primary data FFQ were able to be grouped to correspond to 17/18 food items from the secondary data FFQ. The other 54 primary data food items had no corresponding categories from the secondary data FFQ. The processed food item from the secondary data FFQ was too wide and overlapping with other categories to be able to correspond to specific food items from the primary data FFQ and therefore these were excluded from this comparison.

Table 5.24: Grouped food items from the primary data modified EPIC FFQ and their corresponding food items from the secondary data SHIS FFQ

Secondary data SHIS FFQ food items names	Corresponding food items from the primary data modified EPIC FFQ	Primary data new grouped food items names
Juice	juices	Juices
Fruit	date, pineapple, cantaloupe, watermelon, apricot, apple, pear, mango, grape, orange or mandarin, banana, peach, strawberry, plum, berries, avocado, kiwi	Fruits
Vegetables	green salad, cucumber, spinach, broccoli, cabbage, peas, courgette, cauliflower, shallots, onions, garlic, mushrooms, bell peppers, carrots, lettuce, tomato, pumpkin, corn, beets	Vegetables
Dark fish	tuna and canned fish	Dark fish
Non-dark fish	grilled fish, fried fish	Non-dark fish
Red meat	lamb meat, cow meat, camel meat, meat kebab, grilled meat, liver dish	Red meat
Poultry	chicken, grilled chicken, chicken kebab, shaorma dish, fried chicken	Poultry
Shrimp	shrimp	Shrimp
Processed meat	sausage, meat burger, chicken burger	Processed meat
Processed food	the category is too wide and overlapping with other categories to be specified	N/A
Egg	egg	Egg
Nuts	nuts	Nuts
Milk	whole milk, low-fat milk, fat-free milk	Milk
Labneh	full fat labnah, low-fat labnah, fat-free labnah	Labneh
Laban	full-fat laban, low-fat laban, fat-free laban	Laban
Yoghurt	full-fat yoghurt, low-fat yoghurt, fat-free yoghurt	Yoghurt
Cheese	cream cheese, white cheese, low-fat cheese	Cheese
Soda (carbonated drinks)	carbonated drinks, diet carbonated drinks	Carbonated drinks

SHIS FFQ food items	Corresponding food items from the modified EPIC FFQ	New grouped food items name
N/A	(unallocated food items) white rice, biryani rice, macaroni, white bread, brown bread, pizza (one piece), other baked items, beans, lentils, pastry such as croissant, mashed potato, baked potato, fried potato, asidah, ma'sop, breakfast cereals, falafel sandwich, liver sandwich, meat sandwich, chicken sandwich, shawarma sandwich, egg sandwich, full-fat cream, low-fat cream, fat-free cream, margarine, butter, salted biscuit, sweet biscuit, cake, ice-cream, chocolate, caramel, crisps, nuts such as peanuts, canned fruits such as pineapple, dried fruits, pickles, soup (bowl), sugar (teaspoon) added to tea or coffee, mayo (one spoon), sauces (such as ranch or cheese), ketchup, jam (spoon), red tea (cup), green tea (cup), Arabic coffee, express coffee as cappuccino, decaf coffee, cocoa, canned fruit drinks, condensed fruit drinks (such as Femto)	N/A

Figure 5.25 shows a comparison in the mean daily frequency of consumption between the secondary data food items and their corresponding primary data food items (combined in Table 5.24). Although different in their daily frequency of consumption, both the primary and secondary data food items followed a similar pattern. For example, both patterns show that poultry was consumed more than red meat and red meat was consumed more than eggs.

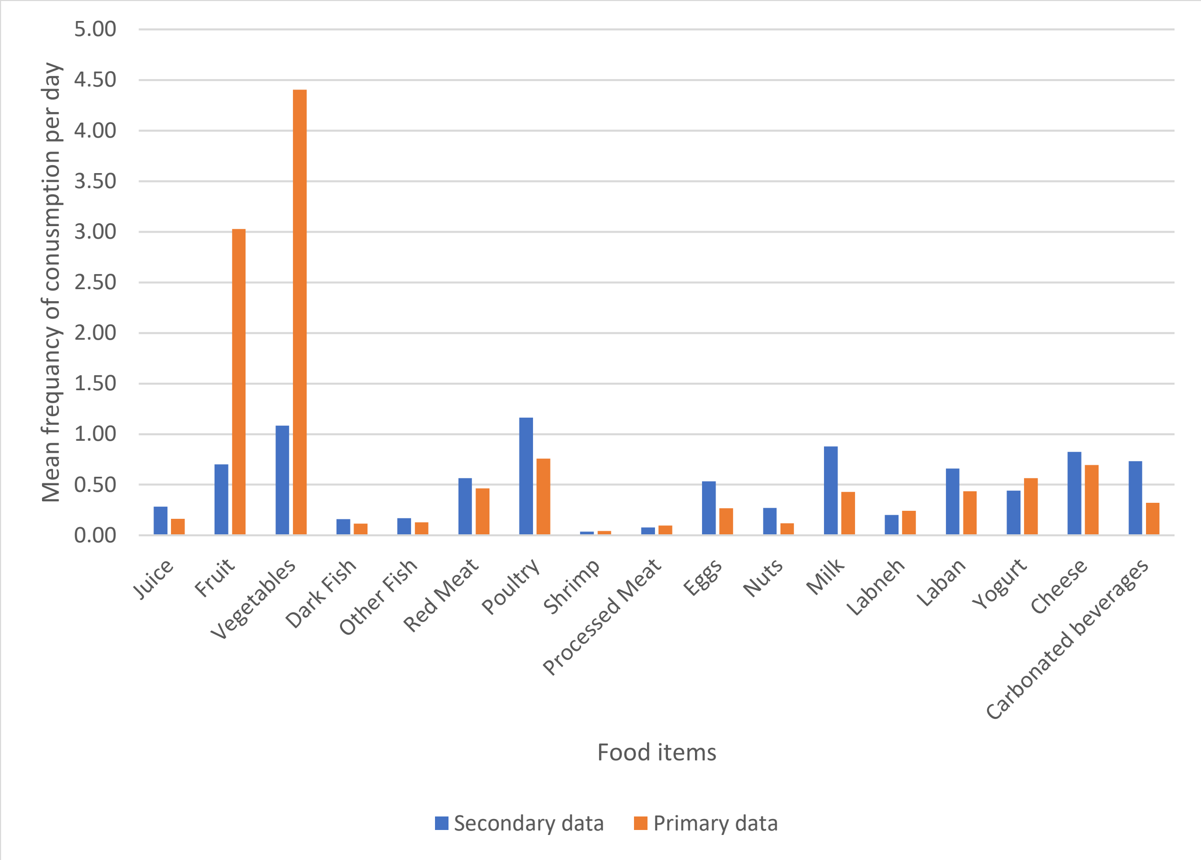

Figure 5.25: Comparison between secondary data food items and their corresponding combined primary data in their pattern and daily frequency of consumption.

The difference in the daily frequency of consumption between the secondary food items and their corresponding combined primary food items can be attributed to having more items initially in the primary FFQ. For example, the category ‘vegetables’ in the secondary data contains 19 corresponding subcategories of vegetables in the primary FFQ. This would result in participants selectively picking each kind of vegetables they would eat in one meal rather than stating that they eat vegetables one time per meal. After that, if vegetable subcategories from the primary FFQ were combined this would explain the higher values reported in comparison with secondary data results.

5.3.7 Section three conclusion

In conclusion, regardless of differences between the study samples and FFQ used for each sample, it was possible to find an overlap between the dietary patterns for the primary and secondary data analysis. For example, the overlap between the secondary data fast food and the primary data fast food and snacking dietary patterns in both their food items composition and their associations with demographic and health factors. These similarities indicate that both study samples overlap in their representation for the same population.

In addition, the over-reporting for some of the FFQ items such as vegetables and fruits discussed in the previous section would not have a major impact in changing the results of factor analysis because factor analysis is based on variable variances rather the size of each value itself (93).

Chapter 6: Discussion and conclusion

6.1 Research aims

The primary aim of this thesis was to explore the relationship between dietary patterns and type 2 diabetes (T2D) through quantifying the association of dietary patterns with glycated haemoglobin (HbA1c) levels among individuals with and without a diagnosis of T2D in Saudi Arabia. The secondary aim of this thesis was to understand the Saudi diet and how it may differ based on different socioeconomic, health and demographic factors.

6.2 The overall associations between T2D, HbA1c, BMI and dietary patterns

The secondary data obtained from the 2013 Saudi National Health Interview Survey (SHIS) (46) factor analysis revealed four dietary patterns that were labelled as Traditional, Dairy Products, Seafood and Processed Foods dietary patterns. In comparison, the factor analysis of the primary data using a more detailed FFQ that has been used in a previous study of diabetes risk in a Saudi population (77) (a modified EPIC FFQ (78)) revealed five dietary patterns that were labelled: Comprehensive, Traditional, Fast Food, Snacking, and Low Processed Food.

In the secondary data, Traditional was found to be associated with higher odds of having undiagnosed T2D and for the primary data, the Low Processed Food dietary pattern was found to be associated with higher odds of having a diagnosis of T2D after adjusting for age and sex, while in the secondary data, Fast Food was associated with lower odds of having T2D after adjusting for age and sex. Additionally, in the primary data, Fast Food and Snacking dietary patterns and, in the secondary data, Traditional dietary patterns were found to be positively associated with HbA1c after adjusting for age and sex. For the primary data, Snacking was also found to be positively associated with BMI after adjusting for age, sex and physical activities. Overall, these findings suggest that some of the dietary patterns are more likely to be associated with a diagnosis of T2D and some patterns are more likely to be associated with higher HbA1c levels than others and this will be discussed in greater detail in the following sections.

6.2.1 The association between dietary patterns and T2D diagnosis

In general, among the dietary patterns identified through the primary and secondary data analysis, the secondary data Traditional dietary pattern was associated with higher odds of having undiagnosed T2D (OR=1.062, CI=1.022-1.104). In contrast, the Low Processed Food dietary pattern was found to be significantly associated with having higher odds of being diagnosed with T2D (OR=1.162, CI=1.115-1.212) which may suggest the possibility that some participants might have changed their diet to include healthier food choices. However, it is also possible that having a diagnosis of T2D prompted some participants to under-report some of the perceived unhealthy food items such as processed foods (i.e. social desirability related response bias).

As data on diet and diagnosis are collected at the same time, the cross-sectional study design has an important limitation regarding the direction of associations (82,103), which means it is difficult to conclude if differences in dietary pattern associations with having a diagnosis of T2D preceded or came after participants were diagnosed with T2D (104). In an attempt to address this limitation, this study examined the association between the dietary patterns and those who had diabetes but had not yet been diagnosed (identified through HbA1c levels). However, the direction of these associations (whether the diet preceded the adverse health outcome or the opposite) is not certain either as participants might still change their diet to lower their BMI, which is also associated with higher levels of HbA1c. This limitation of the cross-sectional study design will be discussed in more detail in Section 6.9.1 of this chapter.

Those who scored high in the secondary data Traditional dietary pattern had higher odds of being an individual with undiagnosed diabetes (identified through HbA1c levels) after adjusting for both age and sex. Therefore, it is possible to assume that the association between the secondary data Traditional dietary pattern did not come after having a T2D diagnosis. However, it is also difficult to exclude reverse associations with other factors such as having prediabetic levels of HbA1c or higher BMI levels.

In contrast, in the secondary data, the Fast Food dietary pattern was found to be associated with having lower odds of having a T2D diagnosis after controlling for both age and sex (OR=0.854, CI=0.765-0.952). However, due to the chance of reverse causality in the cross-sectional study design, it is possible that the Fast Food dietary pattern does not protect against having a diagnosis of T2D, but instead, people eat less Fast Food after having a T2D diagnosis or are still in the process of developing T2D given their younger age relative to those who have developed T2D.

Among all the identified dietary patterns for the primary and secondary data analysis, none can be perceived as entirely "healthy" when considering all the included food items. However, if our assumption that people will try to modify their diet to eat less fast food and more low processed food is true, this indicates an attempt by some of those diagnosed with T2D to eat healthily. This also supports the notion that it is easier and more feasible for people to change their dietary pattern as a whole in line with what people in their community and culture already eat, rather than having a dramatic change that cuts out all unhealthy food items such as fried foods and sweets, and tries to include healthy ones such as vegetables.

The absence of a statistically significant association between most of the other dietary patterns and being diagnosed with T2D may suggest that most of those diagnosed with T2D do not change their diet after having a diagnosis of T2D or that they may have changed their diet after being diagnosed to be more similar to the non-diabetics. Therefore, it is difficult to draw solid conclusions based on comparing those diagnosed with T2D to those who have normal levels of HbA1c.

6.2.2 The association between dietary patterns and HbA1c levels

The secondary data Traditional dietary pattern was found to be positively associated with having higher levels of HbA1c while including both diabetics and non-diabetics and adjusting for age and gender in the analysis (b=0.032, p-value=0.049).

The primary data Fast Food, the primary data Snacking and the secondary data Traditional dietary patterns were found to be positively associated with having higher levels of HbA1c after controlling for age and sex (b=0.182, p-value=0.007; b=0.205, p-value=0.002 and b=0.041, p-value=0.014 respectively). The loss of these associations after excluding those who had a diagnosis of T2D suggests that these associations are either more prominent for those with a diabetes diagnosis in comparison to the total sample or that the decrease in sample size after excluding those with T2D resulted in less statistical evidence to conclude an association. The loss of significance after excluding those diagnosed with T2D may also strengthen the assumption mentioned in the previous section that participants eat less fast food after having a diagnosis of T2D.

The analysis of the association between HbA1c and dietary patterns also shows that the primary data Fast Food and Snacking dietary patterns both, similarly, had a non-significant association with being diagnosed with T2D after controlling for age and sex as was also the case for the secondary data Fast Food dietary pattern. Having similar associations with age and having similarities in their elements suggest that the secondary data Fast Food pattern might be a less detailed version that combines both the primary data Fast Food and Snacking dietary patterns. The similarities between dietary patterns identified in the two datasets will be discussed in more detail in Section 6.3.2.

It was useful to examine the association between the dietary patterns and HbA1c for both diabetics and non-diabetics to help understand the relationship between the identified dietary patterns and blood glucose levels. Recruiting non-diabetics in the study sample to examine the association between diet and HbA1c can help to offer insight into whether some dietary patterns are less associated with the risk of developing diabetes than others.

6.2.3 The association between dietary patterns and BMI levels

After controlling for age, sex and physical activity, the primary data Snacking dietary patterns were found to be positively associated with having higher levels of BMI (b=0.142 p=<0.001). The association between body weight and snacking, in general, is dependent on both the type of foods used as snacks and the frequency of snacking (105–107). A 2009 study has found that frequent between-meal snacking increases the risk for obesity by 66% in comparison to the risk for those who do not snack regularly between meals during a follow-up period of around 4.6 years (107). Another study has found that those with higher BMI levels (> 25 kg/m^2) have reported consuming more foods high in energy density such as chocolate and ice cream while also reporting lower intake of snack items such as nuts in comparison to normal-weight individuals (106).

Many of the Snacking food items included in the primary data Snacking dietary pattern are high energy density foods such as crisps, baked items and confectionery such as chocolate. Therefore, within the Saudi population, it is not surprising that people who have a dietary pattern characterised by the inclusion of high-density snack foods still have a significant positive association with higher BMI level even after adjusting for age, sex and physical activity.

6.3 Dietary patterns explored in more detail within the demographic and health context

There were multiple differences between dietary patterns in terms of demographic characteristics; for example, many of the dietary patterns had a statistically significant association with age in the Saudi population. To understand those differences more, more detail the demographic context of the dietary patterns that showed the strongest associations with health outcomes will be discussed in this section. Those dietary patterns are the Traditional dietary pattern (both from primary and secondary data), the Fast Food dietary pattern (both from the primary and secondary data) and the Snacking dietary pattern (found in the primary data).

6.3.1 The primary and secondary data Traditional dietary pattern

The main items characterising the primary data Traditional dietary pattern are chicken, rice and macaroni, full-fat dairy items, brown bread and fruits. The main items characterising the secondary data Traditional dietary pattern are fruits, poultry, milk and laban. It is worth mentioning again that the secondary data FFQ had only 18 food items and did not include either rice or bread.

Participants who scored high on the primary and secondary data Traditional dietary pattern had no statistically significant association with age. This suggests that Traditional dietary patterns are common across all age groups in Saudi Arabia. This is expected since most Traditional foods are homemade meals which all members of the family consume (108).

Traditional foods have previously been reported to be less damaging regarding health in comparison to Western/Fast Food (109). However, the secondary data Traditional dietary pattern had a significant association with being undiagnosed T2D after controlling for age and sex. Even though the size of the association is very small, the secondary data Traditional dietary pattern was also found to be positively associated with higher BMI and HbA1c levels. Although the Traditional dietary pattern contains only 7 items (due to the secondary data FFQ having only 18 category items), the adverse health associations can be explained partially by including items such as fruits. The most frequently consumed fruit in the Traditional Saudi diet is the date fruit (110). Dates are known for having a high glycaemic load and index (60,111). Also, the Traditional dietary pattern in the secondary data contained the food items poultry and red meat which are usually consumed with rice in the famous Saudi dish Kabsa which is associated with higher odds for developing T2D (19). Unfortunately, there was no question about rice or Kabsa in the secondary data FFQ.

The primary data Traditional dietary pattern was no longer significantly associated with HbA1c, BMI levels and being diagnosed with T2D after controlling for age and sex. Unlike the secondary data Traditional dietary pattern, the primary data Traditional dietary pattern had more food items that appear to be more associated with age such as sugary breakfasts (which was not featured in the secondary data FFQ). The sugary breakfasts include high calorie and high glycaemic Traditional foods such as Asidah (a traditional dish made from flour or dough mixed with butter or honey) (112) and Ma'asoub (a traditional dish made of dough, banana, butter and cream) (113).

6.3.2 The primary and secondary data Fast Food dietary patterns

The main items characterising the primary data Fast Food dietary pattern are processed meat, baked items, fried potato, sugary breakfasts and cold beverages. The main items characterising the secondary data Fast Food dietary pattern are processed meat, processed foods and carbonated drinks.

Participants who scored high in the primary and secondary data Fast Food dietary patterns had a statistically significant negative association with age suggesting that the Fast Food dietary patterns become less common as participants get older. This appears to be a worldwide phenomenon as other studies carried out in other countries such as the USA and Australia have also found that fast food consumption is generally more common among the younger age groups where, for example, those who are younger than 55 consume fast food twice as commonly as those who are older than 55 (114,115).

The result from the primary data analysis has also demonstrated that the Fast Food dietary pattern is more common among males in comparison to females (OR=1.220, CI=1.173-1.269). This is also similar to the results found in studies that were carried out in other countries such as Australia and the USA which also found that males consume fast food more frequently than females (116,117). The USA study found that this difference between males and females in the consumption of fast food is due to females being more concerned about their health and weight than males (117).

The secondary data Fast Food dietary pattern was associated with a higher level of HbA1c while the primary data Fast Food dietary pattern was associated with higher levels of BMI. This reflects the relatively "unhealthy" status of the Fast Food dietary pattern in general which is consistent with previous research that has found that most of the fast food items are high-calorie unhealthy foods such as carbonated drinks that have adverse health associations such as higher BMI levels (66,68,118–120).

6.3.3 The primary data Snacking dietary pattern

The main items characterising the primary data Snacking dietary pattern are processed meat, baked items, confectionary and other sweets, crisps, nuts and pickles. The primary data Snacking dietary pattern had a negative significant association with age suggesting, as with Fast Food, that it is more common among younger age groups in Saudi Arabia. The Snacking dietary pattern had a positive significant association with having higher levels of BMI and HbA1c after adjusting for age and sex.

As mentioned previously in Section 6.2.3, the association between snacking and BMI is dependent on the frequency of snacking and the type of foods included as snacks (105–107). However, from the perspective of the primary data Snacking dietary pattern, which contains many high energy-dense foods, having a significant association with BMI in addition to HbA1c can suggest that the Snacking dietary pattern in the primary data is particularly damaging for health of all the Saudi diets since BMI is closely linked to many other chronic diseases such as coronary heart disease (121).

6.4 Demographic and health characteristics of the study samples

6.4.1 T2D prevalence

There was a difference in T2D prevalence in Saudi Arabia between previous studies and the findings of this research. In a global study that was published in 2014 focusing on the prevalence of diabetes (both type 1 and 2) worldwide, the prevalence of diabetes in Saudi Arabia, when adjusted to the national Saudi population, was estimated to be 20.2% in 2013 (50). The data source for this estimate was acquired from studies published before the SNHS in Saudi Arabia between the years of 1995 and 2011 (122–125). The latest study of those estimates which was published in 2011 estimating diabetes prevalence to be 31.2% and it included both adults and children but only from the city of Riyadh, Saudi Arabia (124).

In comparison, the crude prevalence of T2D in Saudi Arabia found by this research was 11.6% based on analysing the SNHS data which included all regions and attempted to be highly representative of the Saudi population. The overestimation in the prevalence of T2D in studies published before the SNHS data were collected, was also noted by a 2014 study that used the SNHS (2013) data in their analysis (51).

Furthermore, the study published in 2014 about the status of the diabetes epidemic in Saudi Arabia that used the same data acquired from the SHIS found the prevalence of diabetes to be 13.4% while including type 1 diabetics and those who did not know their diabetes type (51). This prevalence is also very close to the T2D prevalence of 11.2% found by the analysis presented in Chapter 5 after excluding outliers and those who reported having type 1 diabetes or those who did not know their diabetes type.

6.4.2 Age and BMI

Both age and obesity are well-established risk factors for T2D (59) and, as expected, the non-diabetic group was younger and less obese than the other two groups of diagnosed and undiagnosed diabetics.

In both primary and secondary data samples, the undiagnosed T2D group was older and with a higher average BMI in comparison to the diagnosed T2D group. This suggests that the undiagnosed group have been affected by T2D at a later age. It is also possible that they developed diabetes at a higher BMI. Having higher BMI among the undiagnosed T2D compared to the diagnosed T2D can also be explained by two possible factors. The first is that those diagnosed with T2D might attempt to lose or maintain weigh in response to their diagnosis. The other factor is that some of the diabetes medication like Metformin (the first line of treatment for T2D) might help to reduce weight by reducing appetite (126).

In a study examining obesity in Saudi Arabia that was published in 2014 and was based on the SHIS data (2013), the prevalence of obesity was found to be 28.7% among the survey sample; it was 33.5% among women and 24.1% among men (58). These findings are supported by the results of the primary and secondary data analysis in the results chapter where women had a higher prevalence of obesity than men. However, the levels of obesity revealed by the analysis in the results chapter among the SNHS sample, excluding the Type 1 diabetics and also those who did not know their diabetes type, was 33.8% which is high compared to the result found by the 2014 study (58). The difference in prevalence could be attributed to the different methods of excluding outliers in the weight and height variables since only extreme outliers (calculated as $Q_{1,3} \pm 3xIQR$) were excluded from the analysis in the previous chapter.

The distribution of T2D prevalence by age suggests that diabetes can affect people predominantly at a relatively younger age in Saudi Arabia (less than 50 years of age) in comparison with other high-income countries where diabetes becomes predominant in older age groups (more than 50) (50). This can also be attributed to factors other than diet and lifestyle such as un-modifiable genetic factors (59).

6.4.3 Smoking status

A study published in 2018 about smoking prevalence in Saudi Arabia found the total prevalence to be 21.1%: 32.5% among males and 3.9% among females (127). This shows an increase among males and a decrease among females in comparison to another study published in 2009 which estimated that the prevalence of smoking among adults in Saudi Arabia was 26.5% among males and 9% among females (128). Having a high ratio of male to female smokers is similar to the results found in this study in both the primary and secondary data (4.2:1 and 13:1 respectively).

Another study, which was published in 2015 and was based on the SHIS data, reported that the total prevalence of people who ever smoked among the survey sample was 16% (129). This prevalence is slightly less than the overall smoker percentage of 17% found by the analysis of the secondary data in the previous chapter and can be explained by having a slightly different denominator, given that type 1 diabetics and those who did not know their diabetes type have been excluded from the SHIS secondary data analysis.

6.4.4 Chronic heart disease

Being diabetic in itself can explain the reason for having a higher prevalence of chronic heart disease for the diagnosed T2D group in comparison with the other groups. Furthermore, having a higher prevalence of smoking could also explain some of that increase in chronic heart disease since smoking is an additional risk factor for chronic heart disease (130). In addition to being younger, the secondary data show that the undiagnosed T2D group has a lower prevalence of smoking than the diagnosed T2D group. This may explain why they have a lower prevalence of chronic heart disease compared to those diagnosed with T2D.

Few studies have examined the prevalence of chronic heart disease while including the total population instead of only high-risk groups in Saudi Arabia. However, a study published in 2004 found the prevalence of coronary artery disease to be 5.5% in Saudi Arabia (131). Based on the data collected in 2013 via the SHIS survey, the prevalence of chronic heart diseases was found not to exceed 0.3% of the secondary data study sample. This could be attributed to response bias where more unhealthy people may choose not to participate in the SHIS (132). There is also the issue of under-reporting since the SHIS relied on self-reporting of disease conditions rather than using health records. It is worth noting as well that the SHIS prevalence found by the current study gives raw prevalence not adjusted for age and sex among the Saudi population.

6.5 Comparison of the dietary patterns with previous studies

In comparing the results of this study with the other 11 studies from the systematic review (Chapter 3) that were undertaken in various MENA region countries, the 11 studies identified 15 dietary patterns that can be compared to this study based on how they were labelled (64,66–73). Among those, eight dietary patterns were labelled as Traditional (64,66,68–73), six dietary patterns were labelled as Fast Food or Western dietary patterns (66–68,71–73) and one dietary pattern was labelled as Snacking (69).

Three of the eight Traditional dietary patterns identified in the systematic review in Chapter 3 (64,69,133) were found to be negatively associated with HbA1c; one study (70) was positively associated with HbA1c while the others (66,71–73) found no association with HbA1c. In comparison, the secondary data Traditional dietary pattern in our study was found to be positively associated with HbA1c. Although they share similar labels, each of the dietary patterns contains different food items that are highly specific to the FFQ used in each study (Table 3.3). Also, the Traditional dietary pattern food items are specific to the Traditional foods in the country of each study. For example, Ma'soub is more specific to Saudi Arabia than Iran (113).

Among the six Fast Food/Western dietary patterns identified in the systematic review in Chapter 3 (66–68,71–73), in three studies these were associated with higher levels of HbA1c (66,67,133) while the other three found no association with HbA1c (71–73). In comparison, the primary data Fast Food dietary pattern was also found to be positively associated with higher levels of HbA1c. The consistent association between dietary patterns labelled as "fast food" (or "Western") and HbA1c can be attributed to the similarity between countries in food items that are labelled as fast food. For example, carbonated drinks were included within the fast food dietary patterns for most of the studies (Table 3.3).

There was one dietary pattern labelled a "snacking" pattern in one of the studies in the systematic review in Chapter 3 (69). This study found no association between the snacking dietary pattern and HbA1c (69). However, the relationship between snacking and health are highly dependent on the frequency and type of foods consumed since not all snacks are high energy-dense foods (105–107). In comparison, the primary data Snacking dietary pattern identified in our study was found to be positively associated with HbA1c, as discussed in Section 6.3.3.

Regarding Saudi Arabia, no previous studies have examined dietary patterns among the general Saudi population while including both diabetics and non-diabetics to examine the relationship between the identified dietary patterns and T2D. Nevertheless, there is a study that was published in 2013 that attempted to examine the relationship between dietary patterns among both type 1 and type 2 diabetic patients (30-79 years in age) recruited from the inpatients' wards in Alnoor hospital in Saudi Arabia using a 74 food item FFQ (69).

The 2013 study identified six dietary patterns, which were named: transitional, healthy, desirable fat, traditional, miscellaneous, and snacking patterns. The most similar dietary patterns from the 2013 study to our study in their food items were the transitional dietary pattern (possibly labelled transitional for containing items that reflect both a traditional and a fast food/Western diet) containing items such as lamb, chicken, egg, rice and milk, which corresponds to the primary data Comprehensive dietary pattern. The transitional pattern was found to be positively associated with higher levels of HbA1c before and after adjusting for age and sex. In comparison, the Comprehensive dietary pattern in our primary data showed a positive association with HbA1c; however, this association was lost after controlling for age and sex. Unfortunately, none of the other 2013 study dietary patterns is similar to the dietary patterns identified in the current studies based on food items, which can make the comparison of their results difficult and potentially misleading. The difference in the identified dietary patterns can be attributed to being collected exclusively from an older in-patient diabetic population in a tertiary care hospital and using an FFQ with a different number and different types of food items.

6.6 Strengths and weaknesses

The current study is the first to be carried out in Saudi Arabia to examine the association between dietary patterns, T2D and HbA1c while also including participants without a T2D diagnosis. Participants in the secondary data set (SHIS, 2013) were randomly recruited from the public, whereas participants included in the primary data set were recruited from primary health care centres. Therefore, both data set samples are expected to be a better representation of the general Saudi population in comparison to an in-patient sample.

As a whole, this study is an exploratory study that focused on exploring associations and differences between dietary patterns and health outcomes such as having a T2D diagnosis, HbA1c level and BMI level using statistical hypothesis testing at a p-value of 0.05. As a result, there is always a 5% chance of Type 1 error where an association or difference is found only due to statistical chance rather than having an actual association or difference (134). Also, there is a chance of a Type 2 error where an association or difference is not statistically found, although it is present (134).

Having those statistical facts in mind, this part of the discussion chapter will also discuss the strengths and limitations of using a cross-sectional study design, using an interview survey and using an FFQ. Also, there will be a discussion regarding the strengths and limitations that were specific to the primary and the secondary data sets.

6.6.1 Strengths and limitations of cross-sectional study design

A cross-sectional study design was used to collect both the secondary data of the SHIS (2013) (46) and the primary data for this study. The cross-sectional study design has the advantages of relatively efficient collection of both exposure and outcome data and requires less expensive resources in comparison with other types of study design such as cohort or case-control (82,103). Also, being conducted at one moment (a snapshot), a cross-sectional study does not have the issue of loss of follow up (82). Such studies may also form the basis of other observational studies including cohort and case-control designs (103). Also, if based on a random population sample, they may be useful in estimating prevalence values among populations (82,103). However, like any other study design, the cross-sectional study design has its limitations.

One of the major limitations of the cross-sectional study design is having measurements taken only at one moment. The loss of the time dimension in the cross-sectional study design makes it more difficult to identify causal relationships between the disease and exposure (82,103). For example, did the participants' diet contribute to their disease development, having a higher BMI level and a higher HbA1c level or did the diagnosis of disease stimulate people to change their diet?

Additionally, having a measurement taken only at one point in time might provide results that differ if measured in another timeframe (82). However, since type 2 diabetes is a long-lasting chronic disease, diagnosis and dietary habits might not change significantly over time; therefore, this might diminish the impact of misclassification of an individual's dietary pattern due to collecting dietary data at only one point in time (103). This is also true for HbA1c where values usually change slowly over several months (7). Thus, this study is interested in the overall diet for participants that would reflect longer periods of time rather than day-to-day changes.

6.6.2 Strengths and limitations associated with interview surveys

As discussed previously in more detail in the method chapter, Section 4.2.2, the benefits of an interview survey include higher response rates, better accuracy and quality of data obtained, while a major weakness is the possibility of inducing social desirability bias (83).

As also discussed previously in Section 6.2.1, the secondary data participants who scored high in the Fast Food dietary pattern had lower odds of being diagnosed with T2D which also might reflect an issue of induced social desirability where participants would under-report food items that they perceived as unhealthy including fast foods items.

6.6.3 Strengths and limitations associated with FFQ

Among different types of dietary assessments such as diet records and 24-hour recall, FFQ has the advantage of being able to measure long-term habitual dietary intake of participants (87). This is particularly useful in assessing associations between diet and diseases that take a long time to develop such as T2D. Furthermore, food frequency questionnaires are more suitable to be administered to a larger sample of participants (87).

One of the limitations with FFQs is that unless modified to be a semi-quantitative questionnaire by adding questions about the estimated portion size, food frequency questionnaires lack information about actual food quantities (87). However, as mentioned previously in the methods chapter, the focus of this research is food patterns; therefore, the frequency of food consumption is more important than the amount of food consumed, although this would be an important aspect to explore in future investigations.

6.6.4 The limitation of using an adapted FFQ

For the primary data collection in this study, an adapted version of the EPIC FFQ (78) that has been used for previous PhD theses has also been used to measure the Saudi diet for the current study. The original EPIC FFQ has been adapted to the Saudi diet through being translated to Arabic, the removal of food items that are not available for consumption for Saudis such as alcoholic beverages and bacon and by adding food items that are more specific to Saudis such as camel meat and fruit such as dates. Unfortunately, the validity of a questionnaire can be compromised by modifying the questionnaire (135). Therefore, one of the limitations of this study is less precision in measuring participants’ diet due to using a questionnaire that has been modified from its validated version (136). However, to maintain as much precision in measuring diet as possible, the EPIC FFQ was modified as minimally as possible to adapt to the Saudi diet.

6.6.5 Primary data weaknesses and strengths

A major strength of this study includes the use of a more inclusive and thorough FFQ containing 125 food items. Another strength was the measurement of HbA1c levels for participants rather than relying only on the reported diagnosis of T2D. HbA1c levels were used as a continuous variable to assess the association between the identified dietary pattern scores and HbA1c level. Also, the inclusion of both diabetic and non-diabetic patients was the main strength that enabled the assessment of whether it was likely that patients significantly changed their diet after a diagnosis of T2D.

One major weakness of this study was the use of a convenient clinical sample rather than having a randomised sample for the primary data study sample. The clinical sample allowed the recruitment of a population of T2D patients and also HbA1c values to be obtained. Although comparison with the secondary data shows that there were differences and similarities between the demographics for both data sets, their dietary analysis suggested overlapping dietary patterns as discussed in Section 6.5.2.

Another weakness was the use of the cross-sectional study design. Although it helped to understand the Saudi population diet and its relationship to T2D, further research using other designs such as a cohort design could help to establish the direction of causality as individuals may change their diet as a result of a diagnosis of prediabetes or diabetes, or to lose weight if they are overweight or obese.

6.6.6 Secondary data weaknesses and strengths

Strengths of the data available from the national survey include the representative nature of the sample, the high response rate, the large sample size and the availability of HbA1c measurements taken at the same time as dietary history. To ensure representation of the sample of the Saudi population, households were picked randomly to be included in the survey (46). In case of no response, each household was revisited two more times before another household was picked. Having an interview survey rather than self-completed questionnaires increased the response rate (83).

However, a weakness of the data available in the context of exploring dietary patterns is the lack of more detailed information on specific food items. The lack of detailed dietary information makes it difficult to categorise the dietary items into more detailed dietary patterns. For example, the category of milk can include both low- and full-fat milk.

It is clear that the SHIS (2013) was not specifically interested in identifying the dietary patterns within the Saudi population; therefore, they only had an 18 item FFQ. Although it was possible to use their 18 food items FFQ to identify some of the patterns within the population, the lack of a detailed FFQ might also conceal some of the dietary patterns. For example, the Snacking dietary pattern was not identified in the SHIS (2013) FFQ in comparison with the more detailed modified EPIC FFQ (78).

A limitation of the analyses was the inability to adjust the prevalence results to the national Saudi population. Adjusting the results would have made it possible to compare the prevalence from this analysis with other studies that adjusted for the Saudi population. However, it was difficult to acquire the Saudi census data stratified by age group and sex for the year 2013 because the General Authority for Statistics in Saudi Arabia does not reveal the exact demographic characteristics of the population in its public estimates (137).

6.7 Implications for policy and practice

As mentioned before, one of the major limitations of cross-sectional studies is the inability to produce an accurate sequencing of the events for the association between exposures and diseases. However, since this study examined dietary patterns in both the population as a whole and for type 2 diabetic patients, the implications of this study can be considered in the context of both T2D prevention and management.

6.7.1 Dietary patterns in the context of T2D prevention

The current Saudi Arabia T2D dietary guidelines (discussed in section 2.6 of the background chapter) are more concerned with the control of current cases of T2D rather than preventing potential cases of T2D among the Saudi population. Therefore, offering guidelines in the context of T2D prevention could potentially help to reduce the incidence rate of T2D in Saudi Arabia.

In the context of T2D prevention, the Snacking dietary pattern was associated with both higher levels of BMI and HbA1c. Therefore, encouraging the population to use healthy alternatives for snacking might help control the incidence of disease and decrease BMI levels. Several previous studies have recommended the role of healthier snacks, such as cheese sticks, fruit and low-fat crisps for the prevention of diabetes (138,139). Also, suggesting healthier snack options can be seen in other countries as a method to improve health as a whole such as seen in change4life dietary guidelines for the UK which suggested for example having fruit slices or hummus with veggie fingers as snacks (140). Therefore, it would be helpful if the Saudi healthy guidelines included information about the importance of limiting the unhealthy options for snacks and suggesting a healthier alternative

The Fast Food dietary pattern was also associated with higher levels of HbA1c. This association is consistent with the findings of previous research (9,66,120). Health policies that discourage the public from consuming fast food, such as decreasing the number of fast foods outlets, might help to decrease the incidence of T2D (120). The current Saudi dietary guidelines for T2D encourage people to avoid foods that were prepared through deep frying or microwaving (34).Whilst use of a microwave oven, for example to cook vegetables, may be a healthy option, it may be included here because in Saudi Arabia it is a common method to prepare fast foods. However, there are other suggestions that could be included in the dietary guidelines to limit the consumption of fast food such as suggesting healthy alternatives for ready to eat and home-prepared takeaway meals. Providing tips for healthier takeaway meals can be also seen in other dietary guidelines such as change4life of the UK which suggested for example having smaller portion sizes (140).

Other options to limit fast food consumption among the Saudi population would be to limit the fast food outlets per area and/or to impose higher taxes on fast foods. Imposing more taxes on unhealthy foods is a common method that aims to limit the burden non-communicable diseases such as T2D and can reach success rates up to 15% (141).

6.7.2 Dietary patterns in the context of T2D management

The current Saudi dietary guidelines (discussed in section 6.2 of the background chapter) shows concern for both having better control for T2D and preventing further possible complications that is commonly associated with T2D such as ischemic heart diseases (142). therefore, for example, it encourages individuals to change their consumption of full-fat items to lower fat items (34). However, changing the guideline to be more focused on dietary patterns that already exist in the population rather than only substituting single items can make the guidelines more feasible for individuals and therefore, provide better control for their T2D.

In the same context of T2D management and control, the primary data Traditional dietary pattern was not found to be significantly associated with HbA1c after controlling for age and sex in contrast with the primary data Fast Food and Snacking dietary patterns. Therefore, encouraging patients to adhere to a more traditional dietary pattern while consuming fewer high energy-dense snack and fast foods might help them in controlling their blood sugar levels (143). In addition, there were no significant association between the traditional dietary pattern and age suggesting that is common among all age groups and therefore, would be easy to comply with regardless of age at diagnosis of T2D.

In the context of T2D management as well, the finding of this study indicates that most diagnosed T2D patients do not change their diet after diagnosis and continue to have higher odds for being smokers. This could be due to believing that medication is enough management for their diabetes rather than it also requiring dietary and lifestyle modifications. Therefore, it can be helpful if the dietary guidelines provide more information about the nature of T2D to convince T2D patients that dietary and lifestyle modification is as important as the medications to manage their condition and even attempt to reverse it.

The result of this study also suggest that some participants might be attempting to modify their diet following their health conditions by switching between dietary patterns that already exist within their community rather than attempting to cut out all foods perceived as unhealthy and including all foods that are perceived as healthy. This possibility emphasises how dietary pattern recommendations might be a more feasible approach for dietary recommendations regarding health.

Furthermore, the finding of this study shows that individuals who are diagnosed with T2D have a higher BMIs level in comparison with individuals who are not diabetic and are more likely to be oebese or overweight. Therefore, encouraging individuals who are diagnosed with T2D to lose weight might not only help them to achieve better control over their blood sugar levels but also, might help them to reverse their condition (40–42).

6.8 Implications for further research

Acknowledging the previously mentioned limitations of cross-sectional study design in Section 6.9.1, the evidence for associations found by this exploratory study can be examined for the possibility of causation by further research using other study designs such as cohort studies and clinical trials. For example, further evidence of the causal association between the primary Snacking dietary pattern and having higher levels of BMI and HbA1c would be provided by cohort studies and by studies examining a dose-response relationship between the consumption of Fast Food or Snacking dietary patterns and risk for T2D for the Saudi population.

Furthermore, intervention studies, including randomised trials of dietary interventions, are required to quantify the potential effectiveness and cost-effectiveness of providing support for modification of dietary habits as an element of diabetes self-management.

Also, further research examining diabetic patients' perception of their medical management is needed to examine the assumption that people in Saudi Arabia might be perceiving their medications as the only management needed for their diabetes, and if true, health policies might attempt to increase T2D patients' awareness regarding the importance of dietary and lifestyle modifications as well as using diabetic medications.

It would also be beneficial to confirm the dietary patterns found in this study, by using a validated FFQ with a larger sample of participants who are more representative of the Saudi population.

6.9 Conclusion

In conclusion, the analysis of the primary data collected through modified EPIC FFQ containing 125 food items has yielded five dietary patterns that are overlapping in terms of their items with analysis of the secondary data acquired from SHIS using an 18-item FFQ which yielded four dietary patterns. Among those dietary patterns, the dietary pattern characterised by consumption of high energy-dense snacking was associated with both higher levels of HbA1c and BMI after controlling for age and sex. The dietary pattern characterised by consumption of fast food was associated with higher levels of HbA1c after controlling for age and sex, while a more traditional dietary pattern lost its positive association with HbA1c after controlling for age and sex. There is a need for population-level diabetes prevention strategies to tackle dietary risks, particularly in younger people who may be establishing lifelong dietary habits that increase their risk of obesity and diabetes in later life. There is also a need to improve diabetes management to ensure that after diagnosis, patients have adequate support to adopt more healthy dietary patterns where indicated.

References:

1. Alharbi NS, Almutari R, Jones S, Al-Daghri N, Khunti K, de Lusignan S. Trends in the prevalence of type 2 diabetes mellitus and obesity in the Arabian Gulf States: systematic review and meta-analysis. Diabetes Res Clin Pr. 2014/09/23. 2014;106(2):e30-3.

2. Olokoba AB, Obateru OA, Olokoba LB. Type 2 Diabetes Mellitus: A Review of Current Trends. Oman Med J. 2012;27(4):269–73.

3. WHO. Diabetes [Internet]. WHO, editor. Vol. 2016, Health topics. 2016 [cited 2020 Apr 19]. Available from: http://www.who.int/topics/diabetes_mellitus/en/

4. Costacou T, Mayer-Davis EJ. Nutrition and prevention of type 2 diabetes. Annu Rev Nutr. 2003;23:147–70.

5. Thomas T, Pfeiffer AF. Foods for the prevention of diabetes: how do they work? Diabetes Metab Res Rev. 2012;28(1):25–49.

6. Eaton SB, Eaton SB. Physical Inactivity, Obesity, and Type 2 Diabetes: An Evolutionary Perspective. Res Q Exerc Sport. 2017;88(1):1–8.

7. (WHO) WHO. Use of glycated haemoglobin (HbA1c) in the diagnosis of diabetes mellitus [Internet]. Vol. 2017. 2011 [cited 2017 May 19]. Available from: http://www.who.int/diabetes/publications/diagnosis_diabetes2011/en/

8. Alhazmi A, Stojanovski E, McEvoy M, Garg ML. The association between dietary patterns and type 2 diabetes: a systematic review and meta-analysis of cohort studies. J Hum Nutr Diet. 2014;27(3):251–60.

9. Al-Khudairy L, Stranges S, Kumar S, Al-Daghri N, Rees K. Dietary factors and type 2 diabetes in the Middle East: what is the evidence for an association?--a systematic review. Nutrients. 2013;5(10):3871–97.

10. Roglic G. WHO Global report on diabetes: A summary. Vol. 1, International Journal of Noncommunicable Diseases. Medknow Publications; 2016. p. 3.

11. Al-Quwaidhi AJ, Pearce MS, Sobngwi E, Critchley JA, O'Flaherty M. Comparison of type 2 diabetes prevalence estimates in Saudi Arabia from a validated Markov model against the International Diabetes Federation and other modelling studies. Diabetes Res Clin Pr. 2014;103(3):496–503.

12. Ripsin CM, Kang H, Urban RJ. Management of blood glucose in type 2 diabetes mellitus. Am Fam Physician. 2009;79(1):29.

13. WHO. Obesity [Internet]. Vol. 2016. WOH; 2016 [cited 2019 May 19]. Available from: http://www.who.int/topics/obesity/en/

14. WHO. Obesity and overweight [Internet]. 3 March 2020. 2020 [cited 2020 Apr 11]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

15. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet. 2014;384(9945):766–81.

16. Langeveld M, DeVries JH. The long-term effect of energy restricted diets for treating obesity. Obesity. 2015;23(8):1529–38.

17. Kahn SE, Cooper ME, Del Prato S. Pathophysiology and treatment of type 2 diabetes: perspectives on the past, present, and future. Lancet. 2014;383(9922):1068–83.

18. Emadian A, Andrews RC, England CY, Wallace V, Thompson JL. The effect of macronutrients on glycaemic control: a systematic review of dietary randomised controlled trials in overweight and obese adults with type 2 diabetes in which there was no difference in weight loss between treatment groups. Br J Nutr. 2015;114(10):1656–66.

19. Farid M. Midhet PHD, Abdulrahman A. Al-Mohaimeed, MD, ABFM, Fawzy K. Sharaf, MD, ABFM. MPH, 768. Lifestyle related risk factors of type 2 diabetes mellitus inSaudi Arabia. Saudi Med J. 2010;31(7):768–74.

20. Moeller SM, Reedy J, Millen AE, Dixon LB, Newby PK, Tucker KL, et al. Dietary patterns: challenges and opportunities in dietary patterns research an Experimental Biology workshop, April 1, 2006. J Am Diet Assoc. 2007;107(7):1233–9.

21. Bisschop PH, de Metz J, Ackermans MT, Endert E, Pijl H, Kuipers F, et al. Dietary fat content alters insulin-mediated glucose metabolism in healthy men. Am J Clin Nutr. 2001/03/10. 2001;73(3):554–9.

22. Mayer-Davis EJ, Monaco JH, Hoen HM, Carmichael S, Vitolins MZ, Rewers MJ, et al. Dietary fat and insulin sensitivity in a triethnic population: the role of obesity. The Insulin Resistance Atherosclerosis Study (IRAS). Am J Clin Nutr. 1997/01/01. 1997;65(1):79–87.

23. Kennedy RL. Nutrition in patients with Type 2 diabetes: are low carbohydratediets effective, safe or desirable? 2005;22.

24. Granfeldt Y, Drews A, Björck I. Arepas made from high amylose corn flour produce favorably low glucose and insulin responses in healthy humans. J Nutr. 1995;125(3):459–65.

25. McKeown NM, Meigs JB, Liu S, Saltzman E, Wilson PW, Jacques PF. Carbohydrate nutrition, insulin resistance, and the prevalence of the metabolic syndrome in the Framingham Offspring Cohort. Diabetes Care. 2004/01/30. 2004;27(2):538–46.

26. Malik VS, Li Y, Tobias DK, Pan A, Hu FB. Dietary protein intake and risk of type 2 diabetes in US men and women. Am J Epidemiol. 2016;183(8):715–28.

27. Van de Wiel A. Alcohol and insulin sensitivity. Neth J Med. 1998;52(3):91–4.

28. Flanagan DE, Moore VM, Godsland IF, Cockington RA, Robinson JS, Phillips DI. Alcohol consumption and insulin resistance in young adults. Eur J Clin Invest.

2000;30(4):297–301.

29. Green A, Shaddick G, Charlton R, Snowball J, Nightingale A, Smith C, et al. A study of obesity, BMI, smoking and alcohol as risk factors for psoriatic arthritis. Br J Dermatol. 2020;182(3):e97–e97.

30. Han TS, Al-Gindan YY, Govan L, Hankey CR, Lean MEJ. Associations of BMI, waist circumference, body fat, and skeletal muscle with type 2 diabetes in adults. Acta Diabetol. 2019;56(8):947–54.

31. Shah M, Garg A. The relationships between macronutrient and micronutrient intakes and type 2 diabetes mellitus in South Asians: A review. J Diabetes Complications. 2019;

32. Cespedes EM, Hu FB. Dietary patterns: from nutritional epidemiologic analysis to national guidelines. Am J Clin Nutr. 2015/04/03. 2015;101(5):899–900.

33. USDA. Scientific report of the 2015 Dietary Guidelines AdvisoryCommittee [Internet]. Vol. 2017. 2015. Available from: https://health.gov/dietaryguidelines/2015-scientific-report/pdfs/scientific-report-of-the-2015-dietary-guidelines-advisory-committee.pdf

34. Ministry of Health SA. National Diabetes Prevention and Control Program [Internet]. [cited 2018 Feb 8]. Available from: http://ndpcp-moh.com/

35. Previdelli ÁN, de Andrade SC, Fisberg RM, Marchioni DM. Using Two Different Approaches to Assess Dietary Patterns: Hypothesis-Driven and Data-Driven Analysis. Nutrients. 2016;8(10):593.

36. Susan M Krebs-Smith. Approaches to Dietary Pattern Analyses: Potential to Inform Guidance [Internet]. 2014 [cited 2018 Apr 15]. Available from: https://health.gov/dietaryguidelines/2015-BINDER/meeting2/docs/workGroupPresentations/DGAC_Patttern_Sue_Krebs_Smith_2-27-14.pdf

37. Reedy J, Wirfält E, Flood A, Mitrou PN, Krebs-Smith SM, Kipnis V, et al. Comparing 3 Dietary Pattern Methods—Cluster Analysis, Factor Analysis, and Index Analysis—With Colorectal Cancer Risk: The NIH–AARP Diet and Health Study. Am J Epidemiol. 2010;171(4):479–87.

38. Esposito K, Maiorino MI, Ceriello A, Giugliano D. Prevention and control of type 2 diabetes by Mediterranean diet: a systematic review. Diabetes Res Clin Pr. 2010;89(2):97–102.

39. Martínez-González MÁ, Fuente-Arrillaga C de La, Nunez-Cordoba JM, Basterra-Gortari FJ, Beunza JJ, Vazquez Z, et al. Adherence to Mediterranean diet and risk of developing diabetes: prospective cohort study. BMJ. 2008;336(7657):1348.

40. Taylor R. Type 2 diabetes: Etiology and reversibility. Diabetes Care. 2013;36(4):1047–55.

41. Lim EL, Hollingsworth KG, Aribisala BS, Chen MJ, Mathers JC, Taylor R. Reversal

of type 2 diabetes: normalisation of beta cell function in association with decreased pancreas and liver triacylglycerol. Diabetologia. 2011;54(10):2506–14.

42. Lean ME, Leslie WS, Barnes AC, Brosnahan N, Thom G, McCombie L, et al. Primary care-led weight management for remission of type 2 diabetes (DiRECT): an open-label, cluster-randomised trial. Lancet. 2018;391(10120):541–51.

43. Taylor R, Al-Mrabeh A, Zhyzhneuskaya S, Peters C, Barnes AC, Aribisala BS, et al. Remission of Human Type 2 Diabetes Requires Decrease in Liver and Pancreas Fat Content but Is Dependent upon Capacity for β Cell Recovery. Cell Metab. 2018;28(4):547-556.e3.

44. Murad MA, Abdulmageed SS, Iftikhar R, Sagga BK. Assessment of the common risk factors associated with type 2 diabetes mellitus in jeddah. Int J Endocrinol. 2014;2014:616145.

45. Guariguata L, Whiting DR, Hambleton I, Beagley J, Linnenkamp U, Shaw JE. Global estimates of diabetes prevalence for 2013 and projections for 2035. Diabetes Res Clin Pract. 2014;103(2):137–49.

46. IHME. Saudi Health Interview Survey Results [Internet]. Ministry of Health of Saudi Arabia in collberation with IHME (institute for health metrics and evaluation) U of W, editor. Vol. 2017. (institute for health metrics and evaluation); 2013 [cited 2017 May 19]. p. 110. Available from: http://www.healthdata.org/ksa/projects/saudi-health-interview-survey

47. Midhet FM, Al-Mohaimeed AA, Sharaf FK. Lifestyle related risk factors of type 2 diabetes mellitus in Saudi Arabia. Saudi Med J. 2010;31(7):768–74.

48. A B, W B, M.E.N L, S B. Indirect Cost Of Diabetes In The Arab Region. Int J Diabetol Vasc Dis Res. 2013;24–8.

49. Alneami YM, Coleman CL. Risk Factors for and Barriers to Control Type-2 Diabetes among Saudi Population. Glob J Heal Sci. 2016;8(9):54089.

50. Guariguata L, Whiting DR, Hambleton I, Beagley J, Linnenkamp U, Shaw JE. Global estimates of diabetes prevalence for 2013 and projections for 2035. Diabetes Res Clin Pr. 2014/03/19. 2014;103(2):137–49.

51. El Bcheraoui C, Basulaiman M, Tuffaha M, Daoud F, Robinson M, Jaber S, et al. Status of the diabetes epidemic in the Kingdom of Saudi Arabia, 2013. Int J Public Health. 2014;1011–21.

52. Daoud F, El Bcheraoui C, Tuffaha M, AlMazroa MA, Al Saeedi M, Nooh RM, et al. The health status of Saudi women: findings from a national survey. J Public Health (Bangkok). 2015;38(4):fdv157.

53. Mokdad A, El Bcheraoui C, Basulaiman M, AlMazroa M, Tuffaha M, Daoud F, et al. Fruit and vegetable consumption among adults in Saudi Arabia, 2013. Nutr Diet Suppl. 2015;Volume 7:41.

54. CDC. Men, younger adults, and people living in poverty get fewest fruits/vegetables

[Internet]. 16/11/2017. 2017 [cited 2010 Apr 12]. Available from: https://www.cdc.gov/media/releases/2017/p1116-fruit-vegetable-consumption.html

55. Moradi-Lakeh M, El Bcheraoui C, Afshin A, Daoud F, Almazroa MA, Al Saeedi M, et al. Diet in Saudi Arabia: Findings from a nationally representative survey. Public Health Nutr. 2016;20(6):1075–81.

56. USDA. United States Department of Agriculture [Internet]. [cited 2019 Mar 5]. p. USDA Food Composition Databases. Available from: https://ndb.nal.usda.gov/

57. Al-Quwaidhi AJ, Pearce MS, Critchley JA, Sobngwi E, O'Flaherty M. Trends and future projections of the prevalence of adult obesity in Saudi Arabia, 1992-2022. East Mediterr Heal J = La Rev santé la Méditerranée Orient = al-Majallah al-ṣiḥḥīyah li-sharq al-mutawassiṭ. 2014;20(10):589.

58. Memish ZA, El Bcheraoui C, Tuffaha M, Robinson M, Daoud F, Jaber S, et al. Obesity and associated factors--Kingdom of Saudi Arabia, 2013. Prev Chronic Dis. 2014;11:E174.

59. Fletcher B, Gulanick M, Lamendola C. Risk factors for type 2 diabetes mellitus. J Cardiovasc Nurs. 2002/01/22. 2002;16(2):17–23.

60. Miller CJ, Dunn E V, Hashim IB. Glycemic index of 3 varieties of dates. Saudi Med J. 2002;23(5):536–8.

61. Tucker KL. Dietary patterns, approaches, and multicultural perspective. Appl Physiol Nutr Metab. 2010;35(2):211–8.

62. CASP UK. CASP Tools & Checklists [Internet]. [cited 2018 Feb 5]. Available from: http://www.casp-uk.net/casp-tools-checklists

63. NIH. Study Quality Assessment Tools | National Heart, Lung, and Blood Institute (NHLBI) [Internet]. [cited 2018 Feb 5]. Available from: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools

64. Elhayany A, Lustman A, Abel R, Attal-Singer J, Vinker S. A low carbohydrate Mediterranean diet improves cardiovascular risk factors and diabetes control among overweight patients with type 2 diabetes mellitus: a 1-year prospective randomized intervention study. Diabetes Obes Metab. 2010;12(3):204–9.

65. Saneei P, Fallahi E, Barak F, Ghasemifard N, Keshteli AH, Yazdannik AR, et al. Adherence to the DASH diet and prevalence of the metabolic syndrome among Iranian women. Eur J Nutr. 2015;54(3):421–8.

66. Naja F, Nasreddine L, Itani L, Adra N, Sibai AM, Hwalla N. Association between dietary patterns and the risk of metabolic syndrome among Lebanese adults. Eur J Nutr. 2013;52(1):97–105.

67. Zad ND, Yusof RM, Esmaili H, Jamaluddin R, Mohseni F. Association of dietary pattern with biochemical blood profiles and bodyweight among adults with Type 2 diabetes mellitus in Tehran, Iran. J Diabetes Metab Disord. 2015;14(1):1–7.

68. Naja F, Hwalla N, Itani L, Salem M, Azar ST, Zeidan MN, et al. Dietary patterns and odds of Type 2 diabetes in Beirut, Lebanon: a case–control study. Nutr Metab (Lond). 2012 Dec 27;9(1):111.

69. Fathia A, AL—lehibie H, Bakhil S, Sci JB-JM, 2013 undefined. Dietary Patterns and Prediction of Risk Factors of Diabetics Patients. docsdrive.com.

70. Study APC. Dietary Patterns Are Associated with Risk of Diabetes Type 2: A Population-Based Case-Control Study. Arch Iran Med. 2016;19(3):166–72.

71. Esmaillzadeh A, Kimiagar M, Mehrabi Y, Azadbakht L, Hu FB, Willett WC. Dietary patterns , insulin resistance , and prevalence of the metabolic syndrome in women 1 – 3. 2007;(1):910–8.

72. Moslehi N, Hosseini-Esfahani F, Hosseinpanah F, Mirmiran P, Azizi F. Patterns of food consumption and risk of type 2 diabetes in an Iranian population: A nested case-control study. Nutr Diet. 2016;73(2):169–76.

73. Doostvandi T, Bahadoran Z, Mozaffari-Khosravi H, Tahmasebinejad Z, Mirmiran P, Azizi F. The association of dietary patterns and the incidence of insulin resistance after a 3-year follow-up: Tehran Lipid and Glucose Study. Asia Pac J Clin Nutr. 2017;26(3):531–8.

74. Bekkouche L, Bouchenak M, Malaisse W, Yahia D. The Mediterranean Diet Adoption Improves Metabolic, Oxidative, and Inflammatory Abnormalities in Algerian Metabolic Syndrome Patients. Horm Metab Res. 2014 Jan 20;46(04):274–82.

75. Amini M, Esmaillzadeh A, Shafaeizadeh S, Nutrition JB-, 2010 undefined. Relationship between major dietary patterns and metabolic syndrome among individuals with impaired glucose tolerance. nutritionjrnl.com.

76. Feinman RD, Pogozelski WK, Astrup A, Bernstein RK, Fine EJ, Westman EC, et al. Dietary carbohydrate restriction as the first approach in diabetes management: critical review and evidence base. Nutrition. 2015;31(1):1–13.

77. Gosadi IM, Goyder EC, Teare MD. Investigating the potential effect of consanguinity on type 2 diabetes susceptibility in a Saudi population. Hum Hered. 2014;77(1–4):197–206.

78. Cancer EPI into. Food Frequency Questionnaire [Internet]. Vol. 2017. EPIC; 2017. Available from: http://www.srl.cam.ac.uk/epic/epicffq/ffq.pdf

79. Moradi-Lakeh M, El Bcheraoui C, Daoud F, Tuffaha M, Kravitz H, Al Saeedi M, et al. Prevalence of asthma in Saudi adults: Findings from a national household survey, 2013. BMC Pulm Med. 2015;15(1):1–7.

80. Basulaiman M, El Bcheraoui C, Tuffaha M, Robinson M, Daoud F, Jaber S, et al. Hypercholesterolemia and its associated risk factors-Kingdom of Saudi Arabia, 2013. Ann Epidemiol. 2014;24(11):801–8.

81. El Bcheraoui C, Memish ZA, Tuffaha M, Daoud F, Robinson M, Jaber S, et al. Hypertension and Its Associated Risk Factors in the Kingdom of Saudi Arabia, 2013:

A National Survey. Int J Hypertens. 2014;2014:1–8.

82. Levin KA. Study design III: Cross-sectional studies. Evid Based Dent. 2006;7(1):24–5.

83. Bowling A. Mode of questionnaire administration can have serious effects on data quality. J Public Health (Bangkok). 2005;27(3):281–91.

84. General Authority for statistics SA. Administrative: Al-Madinah Al-Monawarah [Internet]. Vol. 2017. General Authority for statistics ; 2010. Available from: https://www.stats.gov.sa/sites/default/files/ar-maddinah_1.pdf

85. Riboli E, Hunt KJ, Slimani N, Ferrari P, Norat T, Fahey M, et al. European Prospective Investigation into Cancer and Nutrition (EPIC): study populations and data collection. Public Health Nutr. 2002;5(6b):1113–24.

86. Jiang F, Hou X, Lu J, Zhou J, Lu F, Kan K, et al. Assessment of the performance of A1CNow+ and development of an error grid analysis graph for comparative hemoglobin A1c measurements. Diabetes Technol Ther. 2014;16(6):363–9.

87. SRD Rn, Julie Armstrong MPH, SRD Rphn. A short review of dietary assessment methods used in National and Scottish Research Studies. 2003;

88. Judd SE, Roth DL, Newby PK, Shikany JM, Letter AJ. Dietary Patterns Derived Using Exploratory and Confirmatory Factor Analysis are Stable and Generalizable Across Race, Region, and Gender Subgroups in the REGARDS Study. Front Nutr. 2015;1(January):1–10.

89. Haraldsdóttir J, Holm L, Astrup AV, Halkjær J, Stender S. Monitoring of dietary changes by telephone interviews: results from Denmark. Public Health Nutr. 2001;4(06):1287–95.

90. Acuña E, Rodriguez C. On detection of outliers and their effect in supervised classification. Univ Puerto Rico Mayaguez. 2004;15.

91. Jolliffe I. Principal component analysis. In: International encyclopedia of statistical science. Springer; 2011. p. 1094–6.

92. Shlens J. A tutorial on principal component analysis. arXiv Prepr arXiv14041100. 2014;

93. Costello AB, Osborne JW. Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. Pract assessment, Res Eval. 2005;10(7):1–9.

94. Tobias S, Carlson JE. Brief report: Bartlett's test of sphericity and chance findings in factor analysis. Multivariate Behav Res. 1969;4(3):375–7.

95. Osborne JW, Fitzpatrick DC. Replication analysis in exploratory factor analysis: What it is and why it makes your analysis better. Pract Assessment, Res Eval. 2012;17(15):1–8.

96. Fabrigar LR, Wegener DT, MacCallum RC, Strahan EJ. Evaluating the use of

exploratory factor analysis in psychological research. Psychol Methods. 1999;4(3):272.

97. MacCallum RC, Widaman KF, Zhang S, Hong S. Sample size in factor analysis. Psychol Methods. 1999;4(1):84.

98. Cerny BA, Kaiser HF. A study of a measure of sampling adequacy for factor-analytic correlation matrices. Multivariate Behav Res. 1977;12(1):43–7.

99. Abdi HH. Factor rotations in factor analyses. Encycl Res Methods Soc Sci Sage Thousand Oaks, CA. 2003;792–5.

100. Haynes W. Bonferroni Correction [Internet]. MathWorld--A Wolfram Web Resource. Wolfram Research, Inc.; 2013 [cited 2020 May 1]. p. 154–154. Available from: https://mathworld.wolfram.com/BonferroniCorrection.html

101. Trujillo-Ortiz A, Hernandez-Walls R, Castro-Perez A, Barba-Rojo K, Otero-Limon A. kmo: Kaiser-Meyer-Olkin Measure of Sampling Adequacy. A MATLAB file[WWW Doc URL http//www mathworks com/matlabcentral/fileexchange/loadFile do. 2006;

102. Ferguson E, Cox T. INTERNATIONAL JOURNAL OF SELEC77ON AND ASSESSMENT Exploratory Factor Analysis: A Users' Guide. 1993;1(2):84–94.

103. Setia MS. Methodology series module 3: Cross-sectional studies. Indian J Dermatol. 2016;61(3):261.

104. Chong S, Ding D, Byun R, Comino E, Bauman A, Jalaludin B. Lifestyle changes after a diagnosis of type 2 diabetes. Diabetes Spectr. 2017;30(1):43–50.

105. Forslund HB, Torgerson JS, Sjöström L, Lindroos AK. Snacking frequency in relation to energy intake and food choices in obese men and women compared to a reference population. Int J Obes. 2005;29(6):711–9.

106. O'Connor L, Brage S, Griffin SJ, Wareham NJ, Forouhi NG. The cross-sectional association between snacking behaviour and measures of adiposity: the Fenland Study, UK. Br J Nutr. 2015;114(8):1286–93.

107. Bes-Rastrollo M, Sanchez-Villegas (Almudena, Basterra-Gortari FJ, Nunez-Cordoba JM, Toledo E, Serrano-Martinez M. Prospective study of self-reported usual snacking and weight gain in a Mediterranean cohort: The SUN project. Clin Nutr. 2010;29(3):323–30.

108. Organization WH. Hazard analysis and critical control point generic models for some traditional foods: A Manual for the Eastern Mediterranean Region. 2008;

109. Trichopoulou A, Soukara S, Vasilopoulou E. Traditional foods: a science and society perspective. Trends Food Sci Technol. 2007;18(8):420–7.

110. Assirey EAR. Nutritional composition of fruit of 10 date palm (Phoenix dactylifera L.) cultivars grown in Saudi Arabia. J Taibah Univ Sci. 2015;9(1):75–9.

111. Alkaabi JM, Al-Dabbagh B, Ahmad S, Saadi HF, Gariballa S, Ghazali MA. Glycemic

indices of five varieties of dates in healthy and diabetic subjects. Nutr J. 2011;10:59.

112. Andrews C. Famous Everydat Dishes from the Medieval Arab World [Internet]. 2020 [cited 2020 Feb 26]. Available from: http://www.cliffordawright.com/caw/food/entries/display.php/topic_id/23/id/98/

113. Evelyne. Arabic Breakfast Recipe: Masoub, a Saudi Arabian Banana Breakfast Dish [Internet]. 2020 [cited 2020 Feb 26]. Available from: https://cultureatz.com/masoub-banana-arabic-breakfast-recipe/

114. Anderson B, Lyon-Callo S, Fussman C, Imes G, Rafferty AP. Peer reviewed: Fast-food consumption and obesity among michigan adults. Prev Chronic Dis. 2011;8(4).

115. Mohr P, Wilson C, Dunn K, Brindal E, Wittert G. Personal and lifestyle characteristics predictive of the consumption of fast foods in Australia. Public Health Nutr. 2007;10(12):1456–63.

116. Denney-Wilson E, Okely AD, Hardy L, Crawford D, Dobbins T. Influences on consumption of soft drinks and fast foods in adolescents. 2009;

117. Driskell JA, Meckna BR, Scales NE. Differences exist in the eating habits of university men and women at fast-food restaurants. Nutr Res. 2006;26(10):524–30.

118. Hosseini-Esfahani F, Mirmiran P, Daneshpour MS, Mehrabi Y, Hedayati M, Zarkesh M, et al. Western dietary pattern interaction with APOC3 polymorphism in the risk of metabolic syndrome: Tehran Lipid and Glucose Study. J Nutr Nutr. 2014;7(2):105–17.

119. Borges CA, Marchioni DML, Levy RB, Slater B. Dietary patterns associated with overweight among Brazilian adolescents. Appetite. 2018;123:402–9.

120. Bahadoran Z, Mirmiran P, Hosseini-Esfahani F, Azizi F. Fast food consumption and the risk of metabolic syndrome after 3-years of follow-up: Tehran Lipid and Glucose Study. Eur J Clin Nutr. 2013;67(12):1303–9.

121. Gurka MJ, Filipp SL, Musani SK, Sims M, DeBoer MD. Use of BMI as the marker of adiposity in a metabolic syndrome severity score: derivation and validation in predicting long-term disease outcomes. Metabolism. 2018;83:68–74.

122. Al-Nuaim AR. Prevalence of glucose intolerance in urban and rural communities in Saudi Arabia. Diabet Med. 1997;14(7):595–602.

123. Warsy AS, El Hazmi MA. Diabetes mellitus, hypertension and obesity-common multifactorial disorders in Saudis. 1999;

124. Al-Daghri NM, Al-Attas OS, Alokail MS, Alkharfy KM, Yousef M, Sabico SL, et al. Diabetes mellitus type 2 and other chronic non-communicable diseases in the central region, Saudi Arabia (riyadh cohort 2): a decade of an epidemic. BMC Med. 2011;9:76.

125. Al-Nozha MM, Al-Maatouq MA, Al-Mazrou YY, Al-Harthi SS. Diabetes mellitus in saudi arabia. 2004;

126. Malin SK, Kashyap SR. Effects of metformin on weight loss: potential mechanisms. Curr Opin Endocrinol Diabetes Obes. 2014;21(5):323–9.

127. Algabbani AM, Almubark R, Althumiri N, Alqahtani A, BinDhim N. The Prevalence of Cigarette Smoking in Saudi Arabia in 2018. Food Drug Regul Sci J. 2018;1(1):1.

128. Bassiony MM. Smoking in Saudi Arabia. Saudi Med J. 2009;30(7):876–81.

129. Moradi-Lakeh M, El Bcheraoui C, Tuffaha M, Daoud F, Al Saeedi M, Basulaiman M, et al. Tobacco consumption in the Kingdom of Saudi Arabia, 2013: findings from a national survey. BMC Public Health. 2015;15:611.

130. CDC. Smoking and Diabetes [Internet]. Vol. 2017. 2014 [cited 2019 May 19]. Available from: https://www.cdc.gov/tobacco/data_statistics/sgr/50th-anniversary/pdfs/fs_smoking_diabetes_508.pdf

131. Al-Nozha MM, Arafah MR, Al-Mazrou YY, Al-Maatouq MA, Khan NB, Khalil MZ, et al. Coronary artery disease in Saudi Arabia. Saudi Med J. 2004;25(9):1165–71.

132. Van Loon AJM, Tijhuis M, Picavet HSJ, Surtees PG, Ormel J. Survey non-response in the Netherlands: effects on prevalence estimates and associations. Ann Epidemiol. 2003;13(2):105–10.

133. Khosravi-Boroujeni H, Sarrafzadegan N, Mohammadifard N, Alikhasi H, Sajjadi F, Asgari S, et al. Consumption of sugar-sweetened beverages in relation to the metabolic syndrome among Iranian adults. Obes Facts. 2012;5(4):527–37.

134. Lieber RL. Statistical significance and statistical power in hypothesis testing. J Orthop Res. 1990;8(2):304–9.

135. Moon Z. Adapting and validating questionnaires. Dev Psychol Sect. 2017;51.

136. Steinemann N, Grize L, Ziesemer K, Kauf P, Probst-Hensch N, Brombach C. Relative validation of a food frequency questionnaire to estimate food intake in an adult population. Food Nutr Res. 2017;61(1):1305193.

137. General Authority for Statistics K of SA. General Authority for Statistics [Internet]. Vol. 2018. 2018. Available from: https://www.stats.gov.sa/en

138. Coleman KJ, Ocana LL, Walker C, Araujo RA, Gutierrez V, Shordon M, et al. Outcomes from a culturally tailored diabetes prevention program in Hispanic families from a low-income school. Diabetes Educ. 2010;36(5):784–92.

139. McComber AM, Macaulay AC, Kirby R, Desrosiers S, Cross EJ, Saad-Haddad C. The Kahnawake Schools Diabetes Prevention Project: Community participation in a diabetes primary prevention research project. Int J Circumpolar Health. 1998;57:370–4.

140. NHS. change4life [Internet]. 2020 [cited 2020 Nov 11]. Available from: https://www.nhs.uk/change4life

141. Niebylski ML, Redburn KA, Duhaney T, Campbell NR. Healthy food subsidies and

unhealthy food taxation: A systematic review of the evidence. Nutrition. 2015;31(6):787–95.

142. Messier C, Awad N, Gagnon M. The relationships between atherosclerosis, heart disease, type 2 diabetes and dementia. Neurol Res. 2004;26(5):567–72.

143. NHS. Change4Life [Internet]. 2020 [cited 2020 Apr 26]. Available from: https://www.nhs.uk/change4life/about-change4life

144. Johnstone AM, Murison SD, Duncan JS, Rance KA, Speakman JR. Factors influencing variation in basal metabolic rate include fat-free mass, fat mass, age, and circulating thyroxine but not sex, circulating leptin, or triiodothyronine. Am J Clin Nutr. 2005;82(5):941–8.

Appendices

Appendix 1: List of variables acquired from SHIS for secondary data analysis

Module 2a: Selected Adult Questionnaire for Full Survey

Selected Adult Questionnaire – Full Survey

	Module 2a: Selected Adult Questionnaire	
#	**Question**	**Response**
	Section 1: Sociodemographic Information	
1	Sex (*Record Male / Female as observed)*	Male=1 Female=2
2	How old are you?	Age, in years=1 *Specify in open text field* Don't know=77 Decline to respond=88
3	What is the **highest level of education** you have completed? *[INSERT COUNTRY-SPECIFIC CATEGORIES]* (SELECT ONE)	Can't read or write=1 Can read and write=2 Primary school completed=3 Intermediate school completed=4 High school completed=5 College/University completed=6 Post graduate degree=7 Technical training=8 Don't know=77 Decline to respond=88

4	What is your **marital status**? (SELECT ONE)	Never married=1 Currently married=2 Separated=3 Divorced=4 Widowed=5 Don't know=77 Decline to respond=88
5	Are your parents related (consanguineous marriage)?	First degree cousins=1 Second degree cousins=2 Other relation between them=4 Not related=0 Don't know=77 Decline to respond=88
6	Which of the following best describes your **main work** status over the past 12 months? *[INSERT COUNTRY-SPECIFIC CATEGORIES]* (SELECT ONE)	Government employee=1 Non-government employee=2 Self-employed=3 Non-paid=4 Student=5 Homemaker=6 Retired=7 Unemployed (able to work)=8 Unemployed (unable to work)=9 Don't know=77 Decline to respond=88

7	Can you give an **estimate** of the monthly household income if I read some options to you? Is it *[INSERT QUINTILE VALUES IN LOCAL CURRENCY]* *(READ OPTIONS)*	Less than 3000 Riyal=1 3000 Riyal to less than 5000 Riyal=2 5000 Riyal to less than 7000 Riyal=3 7000 Riyal to less than 10000 Riyal=4 10000 Riyal to less than 15000 Riyal=5 15000 Riyal to less than 20000 Riyal=6 20000 to less than 30000=7 30000 Riyal or more=8 Don't Know=77 Decline to respond=88
#	**Question**	**Response**
	Section 2: Tobacco Use	
1	Now I am going to ask you some questions about various health behaviors. This includes things like smoking, eating fruits and vegetables and physical activity. Let's start with tobacco.	
2	Have you **ever smoked** any **tobacco products**, such as cigarettes, cigars or pipes or Shisha? *(USE SHOWCARD)*	Yes=1 No=0 *If No, go to tobacco_smokeless* Don't know=77 *If Don't know, go to tobacco_smokeless* Decline to respond=88 *If Decline to respond, go to tobacco_smokeless*
3	Do you **currently smoke** any **tobacco products**, such as cigarettes, cigars, pipes or Shisha? *(USE SHOWCARD)*	Yes=1 No=0 *If No, go to tobacco_age_start* Don't know=77 *If Don't know, go to tobacco_age_start* Decline to respond=88 *If Decline to respond, go to tobacco_age_start*
4	Do you currently smoke tobcco products, such as cigarettes, cigars, pipes, or Sisha, daily?	Yes=1 No=0 If *If No, go to tobacco_age_start* Don't know-77 *If Don't know, go to tobacco_age_start* Decline to respond=88 *If Decline to respond, go to tobacco_age_start*

5	How old were you when you **first started** smoking daily?	Age=1 *Specify in open text field* Never smoked daily=0 *If Never smoked daily, go to tobacco_quit* Don't know=77 Decline to respond=88
6	On average, how many **manufactured cigarettes** do you (did you) smoke each day? *(USE SHOW CARD)* (SELECT ONE)	Number of manufactured cigarettes per day=1 *Specify in open text field* Don't know=77 Decline to respond=88
7	On average, how many **hand-rolled cigarettes** do you (did you) smoke each day? *(USE SHOW CARD)* (SELECT ONE)	Number of hand-rolled cigarettes per day=1 *Specify in open text field* Don't know=77 Decline to respond=88
#	**Question**	**Response**
	Section 3: Diet	
	The next questions ask about what you usually eat. I have a nutrition card here that shows you some examples of local food. Each picture represents the size of a serving. As you answer these questions please think of a typical week in the last year.	
1	In a typical week, on how many days do you **eat fruit**? Please include fresh, frozen, or canned fruit, for example figs, grapes, oranges, bananas, or apples. Do not include juices, blended fruits, or dried fruits. *(USE SHOWCARD)*	Number of days=1 *Speficy in open text field, If Zero days, go to diet_juice* Don't Know=77 Decline to respond=88
2	How many **servings** of fruit do you eat on **one** of those days? *(USE SHOWCARD)*	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88

3	In a typical week, on how many days do you **drink 100% fruit juices, including blended fruits**? Do not include “nectars”. *(USE SHOWCARD)*	Number of days=1 *Speficy in open text field, If Zero days, go to diet_vegetables* Don't Know=77 Decline to respond=88
4	How many **servings** of 100% fruit juices do you drink on **one** of those days? (*USE SHOWCARD)*	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
5	In a typical week, on how many days do you **eat vegetables**? Please include raw, cooked, canned, or frozen vegetables. Please do not include rice, potatoes, or cooked dried beans such as kidney beans, pinto beans, or lentils. *(USE SHOWCARD)*	Number of days=1 *Speficy in open text field, If Zero days, go to diet_darkfish* Don't Know=77 Decline to respond=88
6	How many **servings** of vegetables do you eat on **one** of those days? *(USE SHOWCARD)*	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
7	In a typical week, on how many days do you **eat dark meat fish**, such as salmon, tuna fish, mackerel, sardines, bluefish, or swordfish, whether fresh or canned? *(USE SHOWCARD)*	Number of days=1 *Speficy in open text field, If Zero days, go to diet_otherfish* Don't Know=77 Decline to respond=88
8	How many **servings** of dark meat fish do you eat on **one** of those days? *(USE SHOWCARD)*	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
9	In a typical week, how many days do you **eat other fish**?	Number of days=1 *Speficy in open text field, If Zero days, go to diet_redmeat* Don't Know=77 Decline to respond=88

10	How many **servings** of other fish do you eat on **one** of those days?	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
11	In a typical week, how many days do you **eat red meat**?	Number of days=1 *Speficy in open text field, If Zero days, go to diet_poultry* Don't Know=77 Decline to respond=88
12	How many **servings** of red meat do you eat on **one** of those days?	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
13	In a typical week, how many days do you **eat poultry meat** (including chicken)?	Number of days=1 *Speficy in open text field, If Zero days, go to diet_shrimp* Don't Know=77 Decline to respond=88
14	How many **servings** of poultry meat (including chicken) do you eat on **one** of those days?	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
15	In a typical week, how many days do you eat shrimp?	Number of days=1 *Speficy in open text field, If Zero days, go to diet_procmeat* Don't Know=77 Decline to respond=88
16	How many servings of shrimp do you eat on one of those days?	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88

17	In a typical week, how many days do you **eat processed meats** such as sausage, or other packaged cold cuts, lunch meats, or deli meats? Processed meats are meats preserved by smoking, curing, or salting, or by the addition of preservatives. Examples include: pastrami, salami, bologna, other packaged lunch meats or deli meats, sausages, bratwursts, frankfurters, and hot dogs. Please think about all forms of processed meats. Please think about all meals and Snackings including breakfast, lunch, and dinner and food consumed at home and away from home. *(USE SHOWCARD)*	Number of days=1 *Speficy in open text field, If Zero days, go to diet_procfood* Don't Know=77 Decline to respond=88
18	How many **servings** of processed meats do you eat on **one** of those days? *(USE SHOWCARD)*	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
19	In a typical week, how many days do you **eat other processed foods**, such as Fast Food, canned foods, packaged entrees, or soup? *(USE SHOWCARD)*	Number of days=1 *Speficy in open text field, If Zero days, go to diet_eggs* Don't Know=77 Decline to respond=88
20	How many **servings** of other processed foods do you eat on **one** of those days? *(USE SHOWCARD)*	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
21	In a typical week, how many days do you **eat eggs**?	Number of days=1 *Speficy in open text field, If Zero, go to diet_nuts* Don't Know=77 Decline to respond=88
22	How many **servings** of eggs do you eat on **one** of those days?	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
23	Not including peanut butter, in a typical week, on how many days do you **eat peanuts, almonds, walnuts, or any other nuts and seeds**? *(USE SHOWCARD)*	Number of days=1 *Speficy in open text field, If Zero days, go to diet_milk* Don't Know=77 Decline to respond=88

24	How many **servings** of nuts and seeds do you eat on **one** of those days? Please consider a serving to be a 40 grams of nuts or seeds. *(USE SHOWCARD)*	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
25	In a typical week, how many days do you **drink milk**?	Number of days=1 *Speficy in open text field, If Zero, go to diet_laban* Don't Know=77 Decline to respond=88
26	How many **servings** of milk do you usually drink on **one** of those days?	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
27	In a typical week, how many days do you **consume laban**?	Number of days=1 *Speficy in open text field, If Zero, go to diet_yogurt* Don't Know=77 Decline to respond=88
28	How many **servings** of laban do you usually consume on **one** of those days?	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
29	In a typical week, how many days do you **eat yogurt**?	Number of days=1 *Speficy in open text field, If Zero, go to diet_labneh* Don't Know=77 Decline to respond=88
30	How many **servings** of yogurt do you usually consume on **one** of those days?	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
31	In a typical week, how many days do you **consume labneh**?	Number of days=1 *Speficy in open text fiel, If Zero, go to diet_cheese* Don't Know=77 Decline to respond=88

32	How many **servings** of labneh do you usually consume on **one** of those days?	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
33	In a typical week, how many days do you **eat cheese**?	Number of days=1 *Speficy in open text field, If Zero, go to diet_soda* Don't Know=77 Decline to respond=88
34	How many **servings** of cheese do you usually eat on **one** of those days?	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
35	In a typical week, how many days do you **drink regular soda or pop that contains sugar, sweetened iced teas, sports drinks, or fruit drinks**? Do not include diet soda, sugar-free drinks, or 100% pure fruit juice. *(USE SHOWCARD)*	Number of days=1 *Speficy in open text field, If Zero days, go to diet_fat* Don't Know=77 Decline to respond=88
36	How many **servings** of sugar-sweetened beverages do you drink on **one** of those days? *(USE SHOWCARD)*	Number of servings=1 *Specify in open text field* Don't Know=77 Decline to respond=88
37	What type of **oil or fat is most often** used for meal preparation in your household? *(USE SHOWCARD)* (SELECT ONE)	Vegetable oil=1 Olive oil=2 Butter or ghee=3 Margarine=4 Other, please specify=5 *If Other, specify in open text field* None in particular=6 None used=7 Don’t know=77 Decline to respond=88

38	What kind of **Dairy Products** do you **usually** use? (SELECT ONE)	Full fat=1 Low fat=2 Nonfat=3 No preference=4 Don't know=77 Decline to respond=88
39	What kind of bread do you usually eat? (SELECT ONE)	White=1 Brown=2 Saudi-specific bread=3 Don't know=77 Decline to respond=88
40	In a typical week, how many meals do you eat that were **not prepared at a home**? By meal, I mean breakfast, lunch and dinner.	Number of meals=1 *Speficy in open text field* Don't Know=77 Decline to respond=88
41	In a typical week, how many days do you eat **Fast Food**?	Number of meals=1 *Speficy in open text field, must be <=diet_meals_out.number* Don't Know=77 Decline to respond=88
#	**Question**	**Response**
	Section 5: Physical Activity	
	Next I am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person.	
	Work	
	Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/training, household chores, harvesting food/crops, fishing or hunting for food, seeking employment. *[Insert other examples if needed].* In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate; 'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate.	

1	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like *[carrying or lifting heavy loads, digging or construction work]* for at least 10 minutes continuously? *[INSERT EXAMPLES]* *(USE SHOWCARD)* (SELECT ONE)	Yes=1 No=0 *If No, go to work_modactivity* *Don't know=77 If Don't know, go to work_modactivity* *Decline to respond==88 If Decline to respond, go to work_modactivity*
2	In a typical week, on how many days do you do vigorous-intensity activities as part of your work? (SELECT ONE)	Number of days=1 *Specify in open text field* Don't know=77 Decline to respond=88
3	How much time do you spend doing vigorous-intensity activities at work on a typical day? (SELECT ONE)	Hours per day=1 *Specify in open text field* Minutes per day=2 *Specify in open text field* Don't know=77 Decline to respond=88
4	Does your work involve moderate-intensity activity, that causes small increases in breathing or heart rate such as brisk walking *[or carrying light loads]* for at least 10 minutes continuously? *[INSERT EXAMPLES]* *(USE SHOWCARD)* (SELECT ONE)	Yes=1 No=0 *If No, go to travel_walk10* *Don't know=77 If Don't know, go to travel_walk10* *Decline to respond==88 If Decline to respond, go to travel_walk10*
5	In a typical week, on how many days do you do moderate-intensity activities as part of your work? (SELECT ONE)	Number of days=1 *Specify in open text field* Don't know=77 Decline to respond=88

6	How much time do you spend doing moderate-intensity activities at work on a typical day? (SELECT ONE)	Hours per day=1 *Specify in open text field* Minutes per day=2 *Specify in open text field* Don't know=77 Decline to respond=88
	Travel to and from places	
	The next questions exclude the physical activities at work that you have already mentioned. Now I would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to the market, to your place of worship. *[Insert other examples if needed]*	
1	Do you walk for at least 10 minutes continuously to get to and from places? (SELECT ONE)	Yes=1 No=0 *If No, go to rec_vigactivity* *Don't know=77 If Don't know, go to rec_vigactivity* *Decline to respond==88 If Decline to respond, go to rec_vigactivity*
2	In a typical week, on how many days do you walk for at least 10 minutes continuously to get to and from places? (SELECT ONE)	Number of days=1 *Specify in open text field* Don't know=77 Decline to respond=88
3	How much time do you spend walking for travel on a typical day? (SELECT ONE)	Hours per day=1 *Specify in open text field* Minutes per day=2 *Specify in open text field* Don't know=77 Decline to respond=88
	Recreational activities	
	The next questions exclude the work and transport activities that you have already mentioned. Now I would like to ask you about sports, fitness and recreational activities (leisure), *[Insert relevant terms].*	

1	Do you do any vigorous-intensity sports, fitness or recreational *(leisure)* activities that cause large increases in breathing or heart rate like *[running or football]* for at least 10 minutes continuously? *[INSERT EXAMPLES]* *(USE SHOWCARD)* (SELECT ONE)	Yes=1 No=0 *If No, go to rec_modactivity* Don't know=77 *If Don't know, go to rec_modactivity* Decline to respond==88 *If Decline to respond, go to rec_modactivity*
2	In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational *(leisure)* activities? (SELECT ONE)	Number of days=1 *Specify in open text field* Don't know=77 Decline to respond=88
3	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day? (SELECT ONE)	Hours per day=1 *Specify in open text field* Minutes per day=2 *Specify in open text field* Don't know=77 Decline to respond=88
4	Do you do any moderate-intensity sports, fitness or recreational *(leisure)* activities that cause a small increase in breathing or heart rate such as brisk walking, *[swimming, volleyball]* for at least 10 minutes continuously? *[INSERT EXAMPLES]* *(USE SHOWCARD)* (SELECT ONE)	Yes=1 No=0 *If No, go to P16* Don't know=77 *If Don't know, go to P 16* Decline to respond=88 *If Decline to respond, go to P 16*
5	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational *(leisure)* activities? (SELECT ONE)	Number of days=1 *Specify in open text field* Don't know=77 Decline to respond=88

6	How much time do you spend doing moderate-intensity sports, fitness or recreational *(leisure)* activities on a typical day? (SELECT ONE)	Hours per day=1 *Specify in open text field* Minutes per day=2 *Specify in open text field* Don't know=77 Decline to respond=88
	Sedentary behavior	
	The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting with friends, traveling in car, bus, train, reading, playing cards or watching television, but do not include time spent sleeping. *[INSERT EXAMPLES]* *(USE SHOWCARD)*	
1	How much time do you usually spend sitting or reclining on a typical day? (SELECT ONE)	Hours per day=1 *Specify in open text field* Minutes per day=2 *Specify in open text field* Don't know=77 Decline to respond=88
2	In a typical week, how much time do you usually spend in front of the television or on the computer?	Enter number of hours___________=1 Don't know=77 Decline to respond=88
#	**Question**	**Response**
	Section 8: History of Chronic Conditions	
	Now, we are asking about a variety of specific medical events that you may have experienced and medical conditions that you may have been diagnosed with in your lifetime.	

1	Has a doctor or other health professional ever told you that you had a cerebral infarction, otherwise known as a stroke or brain attack? *INTERVIEWER: Do not accept self-diagnosed or diagnosed by a person who is not a doctor or other health professional.* (SELECT ONE)	1=Yes 0=No *(skip to # / cardiacarrest)* 77=Don'tknow *(skip to # / cardiacarrest)* 88=Decline to respond *(skip to # / cardiacarrest)*
2	In what year did you first receive this diagnosis? (SELECT ONE)	Enter year (YYYY): _____ *Specify in open field text* 77=Don'tknow 88=Decline to respond
3	Has a doctor or other health professional ever told you that you had a cardiac arrest, otherwise known as a cardiopulmonary arrest, circulatory arrest, or sudden death? (This is different from a heart attack. This would be a time when you were unconscious because your heart stopped suddenly, and you needed to be revived with CPR or defibrillation paddles.) *INTERVIEWER: Do not accept self-diagnosed or diagnosed by a person who is not a doctor or other health professional.* (SELECT ONE)	1=Yes 0=No *(skip to # / mi)* 77=Don'tknow *(skip to # / mi)* 88=Decline to respond *(skip to # / mi)*
4	In what year did you first receive this diagnosis? (SELECT ONE)	Enter year (YYYY): _____ *Specify in open field text* 77=Don'tknow 88=Decline to respond

5	Has a doctor or other health professional ever told you that you had a myocardial infarction, otherwise known as a heart attack? *INTERVIEWER: Do not accept self-diagnosed or diagnosed by a person who is not a doctor or other health professional.* (SELECT ONE)	1=Yes 0=No *(skip to # / chd)* 77=Don'tknow *(skip to # / chd)* 88=Decline to respond *(skip to # / chd)*
6	In what year did you first receive this diagnosis? (SELECT ONE)	Enter year (YYYY): _____ *Specify in open field text* 77=Don'tknow 88=Decline to respond
7	Has a doctor or other health professional ever told you that you had congestive heart failure, otherwise known as heart failure, cardiomyopathy or having a "weak" heart? *INTERVIEWER: Do not accept self-diagnosed or diagnosed by a person who is not a doctor or other health professional.* (SELECT ONE)	1=Yes 0=No *(skip to # / afib)* 77=Don'tknow *(skip to # / afib)* 88=Decline to respond *(skip to # / afib)*
8	In what year did you first receive this diagnosis? (SELECT ONE)	Enter year (YYYY): _____ *Specify in open field text* 77=Don'tknow 88=Decline to respond
9	Has a doctor or other health professional ever told you that you had atrial fibrillation, otherwise known as irregular rhythm or "A-Fib"? (This is an irregular heart rhythm related to abnormal electrical conduction in the heart.) *INTERVIEWER: Do not accept self-diagnosed or diagnosed by a person who is not a doctor or other health professional.* (SELECT ONE)	1=Yes 0=No *(skip to # / asthma)* 77=Don'tknow *(skip to # / asthma)* 88=Decline to respond *(skip to # / asthma)*

10	In what year did you first receive this diagnosis? (SELECT ONE)	Enter year (YYYY): _____ *Specify in open field text* 77=Don'tknow 88=Decline to respond
11	Has a doctor or other health professional ever told you that you had diabetes mellitus, otherwise known as diabetes, sugar diabetes, high blood glucose, or high blood sugar? *If YES and respondent is female (c1==2):* Was this only when you were pregnant? *INTERVIEWER: Do not accept self-diagnosed or diagnosed by a person who is not a doctor or other health professional.* (SELECT ONE)	1=Yes 2=Yes, but only during pregnancy *(skip to # / predm)* 0=No *(skip to # / predm)* 77=Don'tknow *(skip to # / predm)* 88=Decline to respond *(skip to # / predm)*
12	What type of diabetes do you have?	1=Type 1 2=Type 2 77=I don't know 88=decline to repond
13	During the past 30 days, or since your diagnosis, have you ever taken medication for this condition? (SELECT ONE)	1=Yes, currently taking medication 2=Yes, previously took medication, but not currently 0=No, never took medication 77=Don'tknow 88=Decline to respond
14	Insulin	Yes=1 No=0 Don't know=77 Decline to respond=88
15	Drugs (medication) that you have taken in the past two weeks	Yes=1 No=0 Don't know=77 Decline to respond=88

16	Special prescribed diet	Yes=1 No=0 Don't know=77 Decline to respond=88
17	Advice or treatment to lose weight	Yes=1 No=0 Don't know=77 Decline to respond=88
18	Is there a family history of diabetes, do your parents (father or mother), children, brothers, or sisters suffer from diabetes? (SELECT ONE) ** This variable can help to control the genetic factor**	Yes=1 No=0 Don't know=77 Decline to respond=88
19	Has a doctor or other health professional ever told you that you had pre-diabetes mellitus, otherwise known as pre-diabetes, borderline diabetes, impaired fasting glucose, impaired glucose tolerance, or impaired sugar tolerance? *Show if YES and respondent is female (c1==2):* Was this only when you were pregnant? *INTERVIEWER: Do not accept self-diagnosed or diagnosed by a person who is not a doctor or other health professional.* (SELECT ONE)	1=Yes 2=Yes, but only during pregnancy *(skip to # / renalfail)* 0=No *(skip to # / renalfail)* 77=Don'tknow *(skip to # / renalfail)* 88=Decline to respond *(skip to # / renalfail)*
20	In what year did you first receive this diagnosis? (SELECT ONE)	Enter year (YYYY): _____ *Specify in open field text* 77=Don'tknow 88=Decline to respond

21	Has a doctor or other health professional ever told you that you had hypertension, otherwise known as high blood pressure? *Show if YES and respondent is female (sex==2):* Was this only when you were pregnant? *INTERVIEWER: Do not accept self-diagnosed or diagnosed by a person who is not a doctor or other health professional.* (SELECT ONE)	1=Yes 2=Yes, but only during pregnancy *(skip to # / hce)* 0=No *(skip to # / hce)* 77=Don'tknow *(skip to # / hce)* 88=Decline to respond *(skip to # / hce)*
22	In what year did you first receive this diagnosis? (SELECT ONE)	Enter year (YYYY): _____ *Specify in open field text* 77=Don'tknow 88=Decline to respond
23	Advice or treatment to lose weight	Yes=1 No=0 Don't know=77 Decline to respond=88
24	Has a doctor or other health professional ever told you that you had hypercholesterolemia, otherwise known as high or abnormal blood cholesterol? *INTERVIEWER: Do not accept self-diagnosed or diagnosed by a person who is not a doctor or other health professional.* (SELECT ONE)	1=Yes 0=No *(skip to canev)* 77=Don'tknow *(skip to canev)* 88=Decline to respond *(skip to canev)*
25	In what year did you first receive this diagnosis? (SELECT ONE)	Enter year (YYYY): _____ *Specify in open field text* 77=Don'tknow 88=Decline to respond

26	Has a doctor or other health professional ever told you that you had cancer or a malignancy of any kind? (SELECT ONE)	Yes=1 No=0 *Go to meds_chron_cond (if one of the medication questions in this section==yes) or go to N1a (if no medications taken in this section)* Don't know=77 *Go to meds_chron_cond (if one of the medication questions in this section==yes) or N1a (if no medications taken in this section*) Decline to respond=88 *Go to meds_chron_cond (if one of the medication questions in this section==yes) or N1a (if no medications taken in this section*)
27	In what year did you first receive this diagnosis? (SELECT ONE)	Enter year (YYYY): _____ *Specify in open field text* 77=Don'tknow 88=Decline to respond

	Selected Adult Physical Measurements	
#	**Question**	**Response**
	Section 1: Anthropometry	
	Height Measurement:	
1	Height (in centimeters)	Enter height (cm): *Specify in open text field* Declined measurement or could not measure participant's height=88
	Weight Measurement:	
2	Weight (in kilograms) (To calculate BMI)	Enter weight (kg): *Specify in open text field* Too heavy for scale=2 Declined measurement or could not measure participant's height=88
	Waist Measurement:	
6	Waist circumference (in centimeters) (This is a risk factor for type 2 DM)	Enter waist circumference (cm): *Specify in open text field* Waist circumference was too large to measure=2 Declined measurement or could not measure participant's height=888

Module 4: Selected Adult Biochemical Measurements

Selected Adult Biochemical Measurements

Module 4: Selected Adult Biochemical Measurements	
Question	**Response**
Questions at the clinic	
Section 2: Blood Glucose	
HgbA1c	Enter HgbA1C (%): *Specify in open text field* HgbA1C not measured=0

Appendix 2: The Questionnaire used for the primary data

إستبيان علاقة النوع الثاني من السكري بالأنمطة الغذائية بالمملكة العربية السعودية

Association between type 2 diabetes and dietary pattern in Saudi Arabia survey

Interview information:	معلومات المقابلة:
a- Interviewer name or ID: ---	أ- اسم المقابِل أو رقم المعرف: ---
b- Date (DD/MM/YY): ---	ب _ التاريخ (يوم/شهر/سنة): ---
c- Time (24-hour format): ---	ج- الوقت (بصياغة ال24 ساعة): ---
d- Consent have been obtained: ☐ Yes ☐ No	د- تم أخذ الموافقة: ☐ نعم ☐ لا
e- Do you have diabetes? ☐ Yes, Type 1 (stope the interview here) ☐ Yes, Type 2 ☐ Yes, don't know the type ☐ No ☐ Don't know ☐ Decline tor response	هـ هل أنت مصاب بمرض بالسكري؟ ☐ نعم، النوع الأول (أوقف المقابلة هنا) ☐ نعم، النوع الثاني ☐ نعم، لا أعلم النوع ☐ لا ☐ لا أعلم ☐ يرفض الإجابة
f- Interviewee name: ---	و- اسم المقابَل: ---

g- **Email or phone number for contacting HbA1c results (Optional):** **---** **-----------**	**ز-البريد الإلكتروني أو رقم الهاتف لإبلاغكم بنتيجة فحص HbA1c (اختياري):** **--** **--------------**

Part One: Sociodemographic information:	الجزأ الأول: المعلومات الاجتماعية والديموغرافية:
1- Gender: ☐ Male ☐ Female	1- الجنس: ☐ ذكر ☐ أنثى
2- Age (in years): --- -----------	2- العمر (بالسنوات): -- -------------
3- Marital status: ☐ Never married ☐ Married ☐ Separated ☐ Widowed ☐ Divorced	3- الحالة الاجتماعية: ☐ لم يسبق له الزواج ☐ متزوج ☐ منفصل ☐ أرمل أو أرملة ☐ مطلق
4- Level of education: ☐ Illiterate ☐ Literate with no school education ☐ Primary school ☐ Middle school ☐ High school ☐ Bachelor degree ☐ Post graduate degree	4- مستوى التعليم: ☐ أمي (لا يقرأ أو يكتب) ☐ يقرأ ويكتب ولكن لم يسبق له الذهاب إلى مدرسة ☐ إبتدائي ☐ متوسط ☐ ثانوي ☐ جامعي ☐ ماجستير أو دكتورة
5- Estimate of your household income (in Saudi riyals): ☐ < 5000 ☐ 5000 – 10,000 ☐ 10,000 – 15,000 ☐ 15,000 – 20,000 ☐ > 20,000 ☐ Don't know ☐ Decline to response	5- مجموع الدخل الشهري بالريال السعودي لكل من يعيش معك بالمنزل: ☐ أقل من 5000 ☐ 10,000 – 5000 ☐ 15,000 – 10,000 ☐ 20,000 – 15,000 ☐ أكثر من 20,000 ☐ لا أعلم ☐ يرفض الإجابة

Part Two: Health and Food Frequency Questionnaire	الجزء الثاني: استبيان الحالة الصحية والغذاء

a- Health questionnaire | أ. الاستبيان الصحي

1- Are you or have you ever been a smoker? ☐ Yes ☐ No ☐ Don't know ☐ Decline to response	1- هل أنت مدخن أو كنت مدخن من قبل؟ ☐ نعم ☐ لا ☐ لا أعرف ☐ يرفض الإجابة
2- In a typical week, on how many days do you do intense physical activities as exercises, sports or part of your work (e.g. Lifting heavy loads)? ☐ Number of days .... ☐ Don't know ☐ Decline to response	2- في أسبوع معتاد، كم مرة تمارس نشاط بدني عالي، كالتمارين والرياضة أو كجزء من عملك (حمل مواد ثقيلة)؟ ☐ عدد الأيام .... ☐ لا أعلم ☐ يرفض الإجابة
3- How much time do you spend doing these physical activities on a typical day? ☐ Time (in hours) .... ☐ Don't know ☐ Decline to response ☐ N/A	3- كم من الوقت تمضي في هذه النشاطات البدنية في يوم معتاد؟ ☐ الوقت (بالساعات)......... ☐ لا أعلم ☐ يرفض الإجابة ☐ لا ينطبق
5- If applicable, what medication with doses do you take for your type 2 diabetes? ☐ Insulin, dose: .... ☐ Metformin, dose: .... ☐ Glibenclamide, dose: .... ☐ Gliclazide, dose: .... ☐ Januvia, dose: .... ☐ Galvus, dose: .... ☐ Other: .... Dose: .... ☐ Don't know ☐ Decline to response	5- بحال الإصابة بالسكري من النوع الثاني، ماهي العلاجات والجرعات التي تستخدمها؟ ☐ انسولين، الجرعة: .... ☐ ميتفورمين، الجرعة: .... ☐ جليبنكلاميد، الجرعة: .... ☐ جليكلازيد، الجرعة: .... ☐ جانوفيا، الجرعة: .... ☐ جالفوس، الجرعة: .... ☐ أخرى: .... الجرعة: .... ☐ لا يعلم ☐ يرفض الإجابة
6- Is there a family history of diabetes in your family (parents, siblings or offspring)? ☐ Yes ☐ No ☐ Don't know ☐ Decline to response	6- هل هناك أحد بعائلتك (الوالدين، أو الإخوة والأخوات، أو الأبناء والبنات) مصاب بالسكري؟ ☐ نعم ☐ لا ☐ لا أعلم ☐ يرفض الإجابة
7- Do you have any of those chronic conditions (select all that applies)? ☐ Hypertension ☐ Hypercholesterolemia ☐ Chronic heart disease	7- هل أنت مشخص بأحد هذه الحالات المزمنة (يرجى اختيار كل ما ينطبق)؟ ☐ ارتفاع ضغط الدم ☐ ارتفاع الكوليسترول بالدم ☐ أمراض القلب المزمنة

☐ Asthma ☐ Cancer ☐ Non ☐ Don't know ☐ Decline to response	☐ الربو ☐ السرطان ☐ لا ☐ لا أعلم ☐ يرفض الإجابة
8- Did you change your diet after a diagnosis of diabetes or other chronic disease? ☐ **Yes, after diabetes diagnosis** ☐ **Yes, after other chronic disease diagnosis** ☐ **No** ☐ **N/A** **What are those changes in diet?**	**8- هل قمتم بتغيير نمطك الغذائي بعد التشخيص بمرض السكري أو أحد الأمراض المزمنة؟** ☐ **نعم بعد تشخيص السكري** ☐ **نعم بعد تشخشس مرض مزمن آخر** ☐ **لا** ☐ **لا ينطبق** **ماهي التغييرات بالنمط الغذائي؟**

....
....

....
....

....
....

b- Food Frequency questionnaire: ب- الاستبيان الغذائي:

متوسط الاستهلك Estimated frequency of consumption									نوع الطعام Food type		
+6 يومياً +6 daily	4-5 يومياً 4-5 daily	2-3 يومياً 2-3 daily	مرية يومياً Once daily	5-6 كل أسبوع 5-6 per week	2-4 كل أسبوع 2-4 per week	مرة أسبوعيا Once weekly	1-3 مرات شهري 1-3 per month	لا يأكل مطلقاً أو أقل من مرة في الشهر Never to less than once per month	اللحوم والأسماك Meat and Fish		
									Lamb meat	لحم الضأن	لحوم حمراء Red Meat
									Cow meat	لحم بقري	
									Camel meat	لحم الجمل	
									Meat kabab	كباب لحم	
									Grilled meat	أوصال لحم مشوي	
									Chicken	دجاج (مطبوخ)	دجاج Chicken
									Fried chicken	دجاج(مقلي مثال بروست)	
									Grilled chicken	دجاج(مشوي)	
									Chicken Kabab	كباب دجاج	
									Fried fish	سمك مقلي	بحريات Seafood
									Grilled fish	سمك مشوي	
									Tuna and canned fish	الأسماك المعلبة مثل التونة	
									Shrimp	الروبيان	
									Sausage	نقانق	أخرى

									Shaorma dish	صحن شاورما	Other
									Liver dish	صحن كبدة	

متوسط الاستهلك Estimated frequency of consumption									نوع الطعام Food type		
+6 يومياً +6 daily	5-4 يومياً 4-5 daily	3-2 يومياً 2-3 daily	مرية يومياً Once daily	6-5 كل أسبوع 5-6 per week	4-2 كل أسبوع 2-4 per week	مرة أسبوعيا Once weekly	3-1 مرات شهري 1-3 per month	لا يأكل مطلقاً أو أقل من مرة في الشهر Never to less than once per month	الخبز والحبوب Bread and Grains		
									White rice	رز أبيض	أرز ومعكرونة Rice & Macaroni
									Brinay rice	رز برياني أو أحمر	
									Macaroni	معكرونة	
									White bread	خبز أبيض	خبز و بيتزا ومعجنات Bread, pizza & baked items
									Brown bread	خبز بر(أسمر)	
									Pizza (one piece)	بيتزا(قطعة واحدة)	
									Baked items	المعجنات	
									Mashed potato	بطاطا مهروسة	بطاطا Potato
									Baked potato	بطاطا مسلوقة	
									Fried potato	بطاطا مقلية	
									Asidah	عصيدة	إفطار Breakfast
									Ma'sop	معصوب	

									Breakfast cereals	حبوب الإفطار(كورن فليكس)	

متوسط الاستهلك Estimated frequency of consumption									نوع الطعام Food type		
+6 يومياً +6 daily	5-4 يومياً 4-5 daily	3-2 يومياً 2-3 daily	مرية يومياً Once daily	6-5 كل أسبوع 5-6 per week	4-2 كل أسبوع 2-4 per week	مرة أسبوعيا Once weekly	3-1 مرات شهري 1-3 per month	لا يأكل مطلقاً أو أقل من مرة في الشهر Never to less than once per month	السندويشات والبرجر Sandwiches and burgers		
									Liver sandwich	ساندويتش كبدة	ساندويشات Sandwiches
									Egg sandwich	ساندويتش بيض	
									Meat sandwich	ساندويتش لحم	
									Chicken sandwich	ساندويتش دجاج	
									Falafel sandwich	ساندويتش فلافل	
									Shawarma	شاورما	
									Meat burger	برقر لحم	برجر Burger
									Chicken burger	برقر دجاج	
متوسط الاستهلك Estimated frequency of consumption									نوع الطعام Food type		
+6 يومياً +6 daily	5-4 يومياً 4-5 daily	3-2 يومياً 2-3 daily	مرية يومياً	6-5 كل أسبوع	4-2 كل أسبوع	مرة أسبوعيا	3-1 مرات شهري	لا يأكل مطلقاً أو أقل من مرة في الشهر	الألبان والدهون Dairy Products		

			Once daily	5-6 per week	2-4 per week	Once weekly	1-3 per month	Never to less than once per month			
									Cream cheese	جبنة سائلة	أجبان Cheese
									White cheese	جبنة بيضاء	
									Low-fat cheese	جبنة قليلة الدسم	
									Full-fat cheese	زبادي كامل الدسم	زبادي Yogurt
									Low-fat yogurt	زبادي قليل الدسم	
									Fat-free yogurt	زبادي خالي الدسم	
									Full-fat cream	قشطة كاملة الدسم	قشطة Cream
									Low-fat cream	قشطة قليلة الدسم	
									Fat-free cream	قشطة خالية الدسم	
									Full-fat labnah	لبنة كاملة الدسم	لبنة Labnah
									Low-fat labnah	لبنة قليلة الدسم	
									Fat-free labnah	لبنة خالية الدسم	
									Whole milk (cup)	حليب كامل الدسم (كوب)	حليب Milk
									Low-fat milk (cup)	حليب قليل الدسم (كوب)	
									Fat-free milk (cup)	حليب خالي الدسم (كوب)	
									Full-fat laban	لبن كامل الدسم (كوب)	لبن

									Low-fat laban	لبن قليل الدسم (كوب)	Laban
									Fat-free laban	لبن خالي الدسم (كوب)	
									Mayo (one spoon)	مايونيز(ملعقة كبيرة)	دهون و بيض Fat & eggs
									Butter (tea spoon)	زبدة (ملعقة صغيرة)	
									Margarine	سمن(ملعقة صغيرة)	
									Egg (one egg)	بيض(حبة)	

متوسط الاستهلك Estimated frequency of consumption									نوع الطعام Food type		
+6 يومياً +6 daily	4-5 يومياً 4-5 daily	2-3 يومياً 2-3 daily	مرية يومياً Once daily	5-6 كل أسبوع 5-6 per week	2-4 كل أسبوع 2-4 per week	مرة أسبوعيا Once weekly	1-3 مرات شهري 1-3 per month	لا يأكل مطلقاً أو أقل من مرة في الشهر Never to less than once per month	الحلويات والوجبات الخفيفة Sweets and snakes		
									Salted biscuit	البسكويت المملح	الوجبات الخفيفة Snakes
									Sweet biscuit	البسكويت الحلو	
									Cake	الكيك	
									Pastry as Croesan	الكعك والفطائر مثل الكروسان	
									Chips	رقائق البطاطا مثل ليز وغيره	
									Nuts as peanuts	المكسرات مثل الفول السوداني وغيره	

									Pickles	المخللات	
									Soup (bowl)	حساء(وعاء)	
									Ice-cream	المثلَجات(الآيسكريم)	السكريات Sweets
									Chocolate	الشوكولاتة مثل كيتكات	
									Sugar (tea spoon) added to tea or coffee	السكر(ملعقة صغيرة) المضاف للشاي والقهوة	
									Caramel	كريم كراميل	
									Jam (spoon)	مربى البرتقال(ملعقة صغيرة)	
									Sauces (as ranch or cheese)	الصلصات (ملعقة كبيرة) مثل صلصة الرانش وصلصة الجبن	صلصات Sauces
									Ketchup	كاتشب	

متوسط الاستهلك Estimated frequency of consumption									نوع الطعام Food type		
+6 يومياً +6 daily	5-4 يومياً 4-5 daily	3-2 يومياً 2-3 daily	مرية يومياً Once daily	6-5 كل أسبوع 5-6 per week	4-2 كل أسبوع 2-4 per week	مرة أسبوعيا Once weekly	3-1 مرات شهري 1-3 per month	لا يأكل مطلقاً أو أقل من مرة في الشهر Never to less than once per month	المشروبات Drinks		
									Red tea (cup)	شاي أحمر (كوب)	شاي Tea
									Green tea (cup)	شاي أخضر (كوب)	

									Arabic coffee	القهوة العربية (فنجان)	قهوة وكاكاو Coffee & cacao
									Express coffee as cappuccino (cup)	القهوة سريعة التحضير مثل الكابتشينو (كوب)	
									Decaf coffee	القهوة الخالية من الكافيين (كوب)	
									Cacao	الكاكاو والشوكولا الساخنة (كوب)	
									Sodas	المشروبات الغازية مثل البيبسي (علبة)	غازيات Carbonated beverages
									Diet sodas	المشروبات الغازية منخفضة السعرات الحرارية مثل بيبسي دايت (علبة)	
									Juices and smoothies with no sugar added	عصير الفاكهة الطازج من غير إضافة سكر	عصائر Juices & smoothies
									Caned Fruit drinks	شراب الفاكهة المعلب	
									Condensed fruit drinks (as Femto)	شراب الفواكه المخفوقة أو المركزة مثل الفيتمو (كأس)	

متوسط الاستهلك Estimated frequency of consumption									نوع الطعام Food type
+6 يومياً +6 daily	4-5 يومياً 4-5 daily	2-3 يومياً 2-3 daily	مرية يومياً	5-6 كل أسبوع	2-4 كل أسبوع	مرة أسبوعيا	1-3 مرات شهري	لا يأكل مطلقاً أو أقل من مرة في الشهر	الفواكه Fruits

			Once daily	5-6 per week	2-4 per week	Once weekly	1-3 per month	Never to less than once per month		
									Date	التمر(ثمرة)
									Apple	التفاح(ثمرة)
									Pear	الكمثرى(ثمرة)
									Mango	المانجو(ثمرة)
									Grape	العنب(عنقود)
									Orange or margarines	البرتقال او اليوسفي(ثمرة)
									Pineapple	أناناس(شريحة)
									Cantaloupe	الشمام(شريحة)
									Banana	الموز(ثمرة)
									Watermelon	البطيخ او الجح(شريحة)
									Peaches	الخوخ(ثمرة)
									Strawberries	الفراولة(ثمرة)
									Plum	البرقوق(ثمرة)
									Apricots	المشمش(ثمرة)
									Berries	التوت
									Avocado	أفوكادو
									Kiwi	الكيوي
									Caned fruits as pineapple	الفواكه المعلبة مثل الخوخ والأناناس

									Dried fruits الفواكه المجففة مثل الزبيب والبرقوق

متوسط الاستهلك Estimated frequency of consumption									نوع الطعام Food type
+6 يومياً +6 daily	4-5 يومياً 4-5 daily	2-3 يومياً 2-3 daily	مرية يومياً Once daily	5-6 كل أسبوع 5-6 per week	2-4 كل أسبوع 2-4 per week	مرة أسبوعيا Once weekly	1-3 مرات شهري 1-3 per month	لا يأكل مطلقاً أو أقل من مرة في الشهر Never to less than once per month	الخضار Vegetables
									Green salad سلطة خضراء
									Cucumber الخيار
									Pumpkin القرع
									Spanish السبانخ
									Broccoli البروكلي
									Cabbage الكرنب(الملفوف)
									Peas البازلاء
									Beans الفول
									Courgettes الكوسه
									cauliflower القرنبيط
									Shallots الكراث
									Onions البصل
									Garlic الثوم

									Mushrooms	فطر(المشروم)
									Bell peppers	الفلفل الحلو(الفلفل الرومي)
									Carrots	الجزر
									Lettuce	الخس
									Tomato	الطماطم
									Corn	الذرة
									Beets	جذر الشمندر (البنجر)
									Lentils	العدس

Part three: Physical and laboratory information:	الجزء الثالث: المعلومات البدنية والمختبرية:
1- Height (cm): ---	**1- الطول (بالسنتيمتر):** ---
2- Weight (Kg): ---	**2- الوزن (بالكيلوغرام)** ---
3- HbA1c level (%): ---	**3- مستوى الHbA1c (%):** ---

Appendix 3: The Consent used for the primary data

دراسة حول علاقة النوع الثاني من السكري بالأنماط الغذائية بالمملكة العربية السعودية

Association between T2D and dietary pattern in Saudi Arabia

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Study objective :

A dietary pattern is the combination of drinks and food we eat. The purpose of this study is to identify which dietary patterns are most likely to associate with type 2 diabetes in Saudi Arabia.

هدف الدراسة:

النمط الغذائي هو مجموع المشروبات والأطعمة التي نتانولها، هذه الدراسة تهدف إلى تحديد تلك الأنمطة الغذائية التي قد تساعد على الإصابة بالنوع الثاني من مرض السكري في المملكة العربية السعودية.

Study procedures:

You will be asked questions regarding your health and diet during an interview survey then will be asked to give a drop of blood sample using a disposable fingersticks to be used for HbA1c test which can help to identify wither you have diabetes or in a pre-diabetic state.

خطوات الدراسة:

الدراسة عبارة عن أسئلة سيتم طرحها عليك تتعلق بصحتك ونمطك الغذائي، وبعد ذلك سوف يطلب منك إعطاء عينة دم من اصبع الإبهام (قطرة) باستخدام نكاشة طبية تستعمل لمرة واحدة لعمل اختبار HbA1c والذي سيحدد إذا ماكنت مصاباً أو في طريقة الإصابة للسكري لا سمح الله.

Study benefits:

This study will help future dietary management guidelines for type 2 diabetes. A direct benefit for participating in this study is receiving HbA1c result if Email or contact number is included (optional).

فوائد الدراسة:

هذه الدراسة ستاهم بوضع قواعد ارشادية لمرضى النوع الثاني من السكري فيما يخص الغذاء. وكفائدة مباشرة للمشاركة بهذه الدراسة، سيتم إرسال نتيجة اختبار HbA1c إلى هاتفك إذا اخترت اضافة الإيميل او رقم الهاتف (اختياري).

Study risks:

There are no risks for participating in this study. You can withdraw anytime without the need to give a reason.

خطورة الدراسة:

هذه الدراسة لا تمثل أي خطورة للمشاركين فيها. يمكن الانسحاب في أي وقت أثناء الدراسة دون الحاجة لإعطاء سبب.

Confidentiality:

All of your response to this questionnaire will be kept anonymous. Your personally

السرية:

جميع إجاباتك سوف تكون سرية، ولن يتم إظهار معلوماتك الشخصية على أي مكان في هذه الدراسة.

identifying information will not be used anywhere in this study.

Consent:

I have read and I understand the provided information and have had the opportunity to ask questions. I understand that my participation is voluntary and I can withdraw at any time, without giving a reason or contact the researcher to ask more questions. I voluntarily agree to take part in this study and by signing this consent, I don´t give up any of my legal rights. I have informed to obtain a copy of this consent.

Name & signature Date

....

الموافقة:

لقد قرأت وفهمت المعلومات المزودة أعلاه، وتم إعطائي فرصة لطرح مزيد من الأسئلة بخصوص الدراسة. أنا أعلم ان اشتراكي بهذه الدراسة اختياري ويمكنني الإنساحب بأي وقت دون الحاجة لإعطاء سبب. وفهمت أن بإمكاني التواصل مع الباحث بأي وقت لطرح أسئلة أخرى. أنا أوافق للمشاركة بهذه الدراسة وبتوقيعي على هذا النموذج، أنا لا أتنازل عن أي حق من حقوقي القانونية.

تم إعلامي كذلك بالحصول عن نسخة من هذا النوذج للاحتفاظ به.

الاسم والتوقيع التاريخ

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Appendix 4: Additional analysis for the secondarily acquired SHIS data:

Secondary data sample distribution by diagnosis groups

The distribution of diagnosed and undiagnosed T2D cases among the age groups 18-29 years, 30-39 years, 40-49 years, 50-59 years, 60-69 years and 70 or more years is presented in Figure 5.2. Diagnosed T2D had its prevalence increase as the study sample grew older reaching its highest values among the age group 60-69 years and the equal to or above 70. Undiagnosed T2D had the highest prevalence among the age group 50-59 years. The prevalence of diagnosed T2D was zero in cases younger than 18 years old.

The distribution of the diagnosis groups by sex is shown in Figure 5.3. Males had a slightly higher proportion of being diagnosed with T2D (4.6%) compared to females (3.2%).

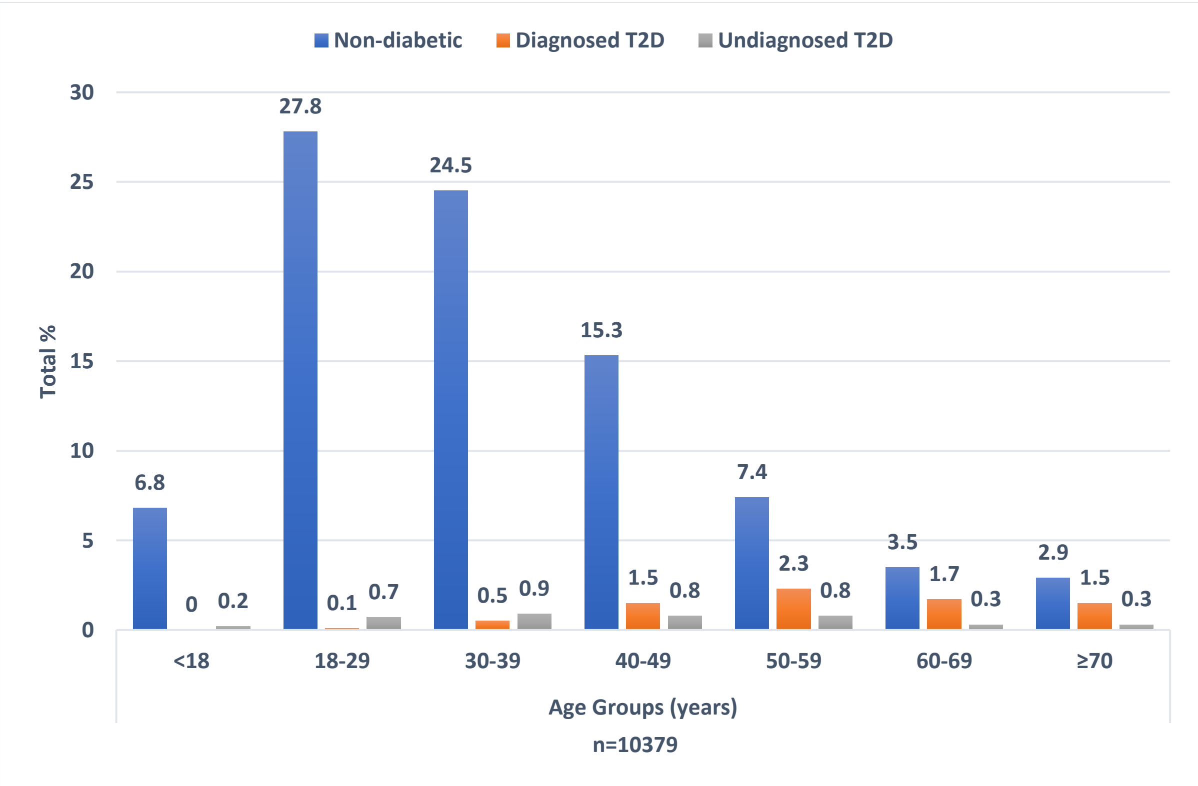

Figure 5.2: Secondary data distribution of diagnosis group proportions by age group

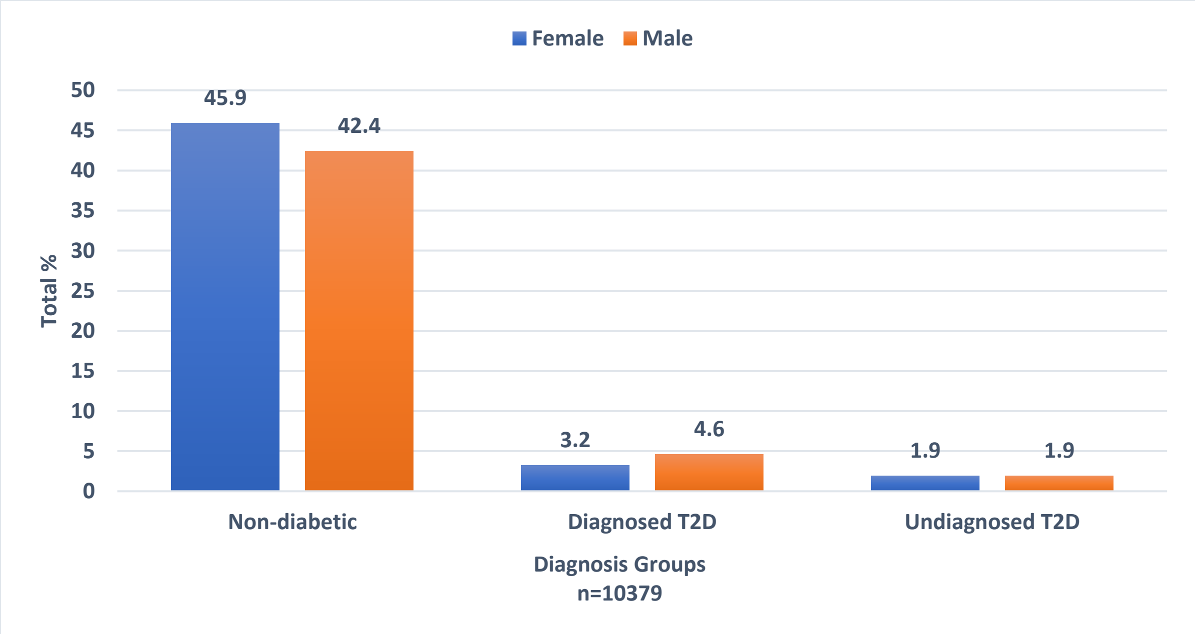

Figure 5.3: Secondary data distribution of diagnosis group proportions by sex

Secondary data sample distribution by HbA1c levels

HbA1c level distribution within age groups shows that the proportion diagnosed with T2D within the secondary data sample is highest in the 18-29-year age group (5.1%) (Figure 5.4). This decreases gradually until it reaches its lowest point in the 60-69 (0.9%) age group. The proportions for pre-diabetics follows a similar pattern with the highest point starting in the 18-29-year age group (2.4%) and gradually decreasing until it reaches its lowest point in the 70 or more-year age group (0.5%).

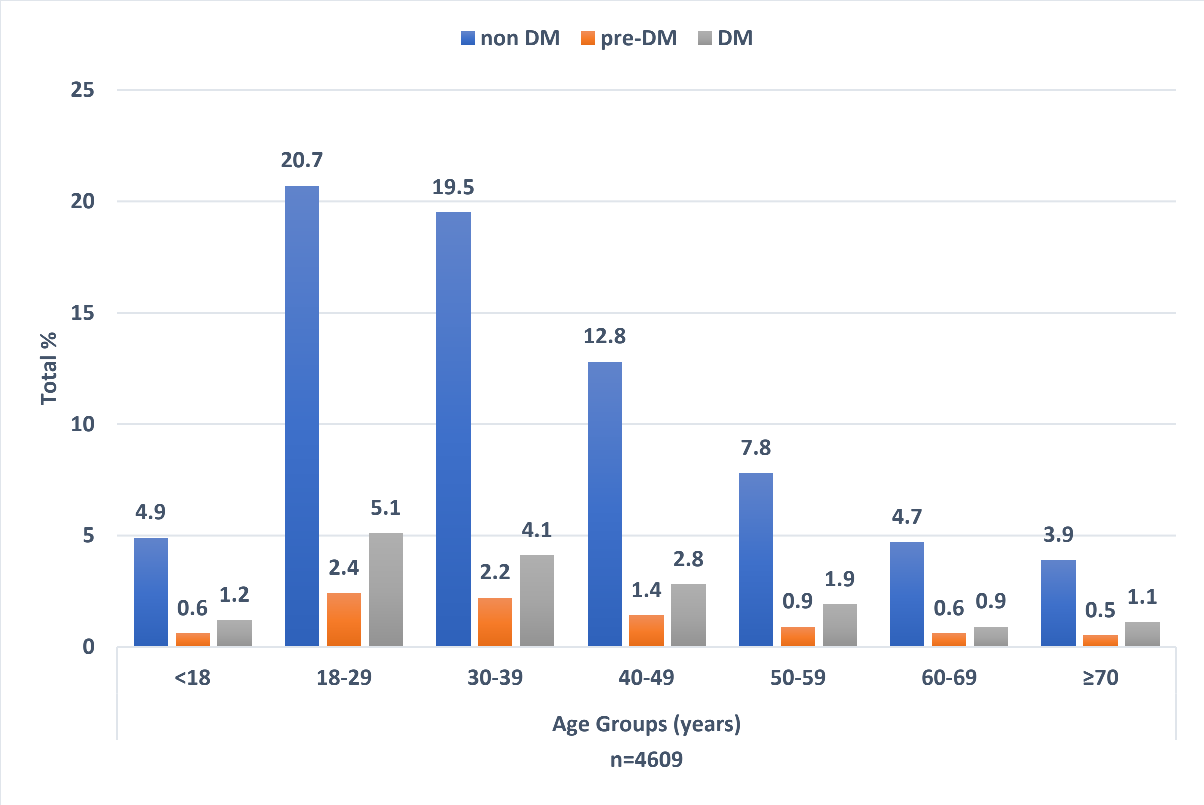

Figure 5.4: Secondary data distribution of HbA1c diagnosis groups by age group

The distribution of the HbA1c diagnosis groups according to sex follows a pattern similar to the one seen in the diagnosis group distributions (Figure 5.3) where the males have a slightly higher proportion for both the diabetics' and the pre-diabetics' level of HbA1c (Figure 5.5).

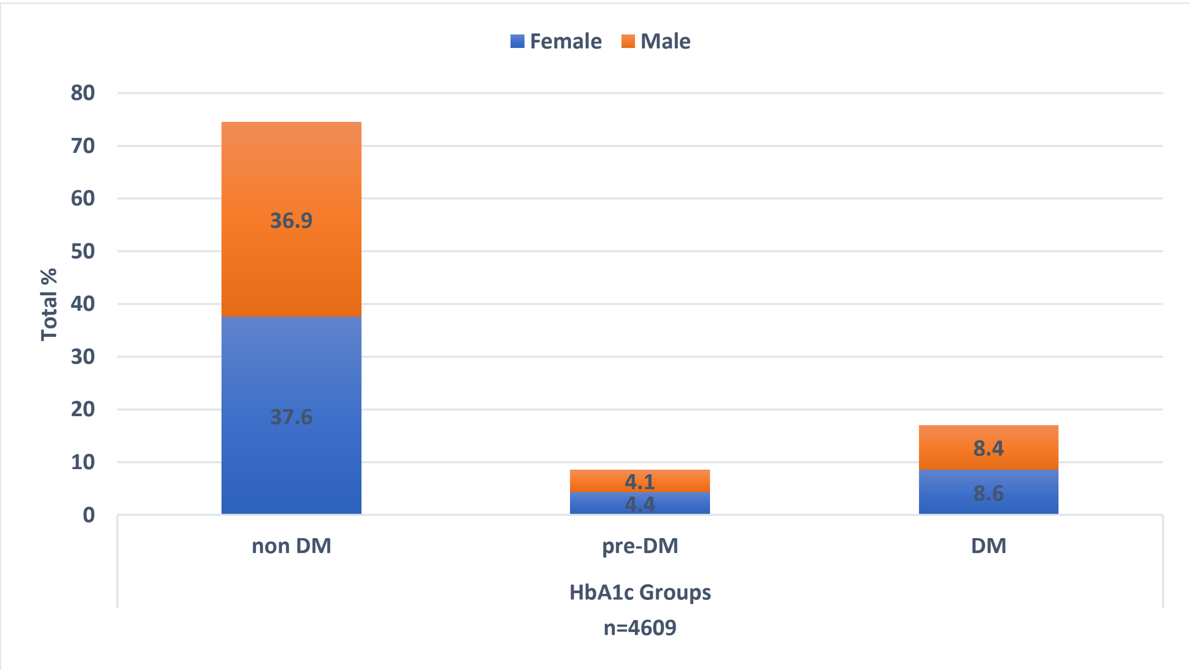

Figure 5.5: Secondary data distribution of HbA1c diagnosis groups by sex

Secondary data sample distribution by HbA1c levels (excluding diagnosed T2D)

After excluding participants who have a T2D diagnosis (who are also taking medication to help control blood glucose levels), the distribution of HbA1c levels within age groups can be seen in Figure 5.6. This follows the same pattern seen in Figure 5.4 with slightly higher numbers due to removing those with a diagnosis who had been prescribed blood glucose controlling medications. Those with diabetic levels of HbA1c are most numerous in the 18-29-year age group (5.7) and this then gradually decreased to the lowest point in the 60-69-year age group (0.05%). There is a slight increase in the proportion of those who have pre-diabetic levels of HbA1c as well as the highest point in the 18-29-year age group (2.7%) and after that it decreases until it reaches its lowest point in the 60-69-year age group (0.4%).

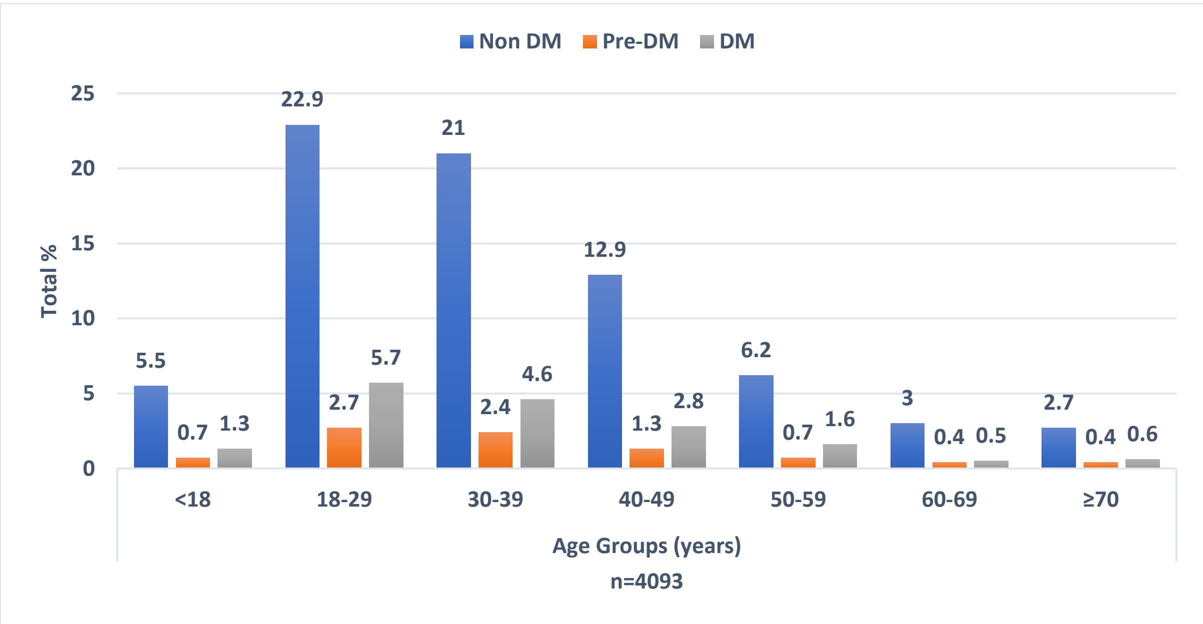

Figure 5.6: Secondary data distribution for HbA1c diagnosis groups (excluding T2D) by age group

Sex distribution of the HbA1c groups after excluding diagnosed T2D can be seen in Figure 5.7, showing females have a slightly higher proportion of undiagnosed diabetes and of prediabetes

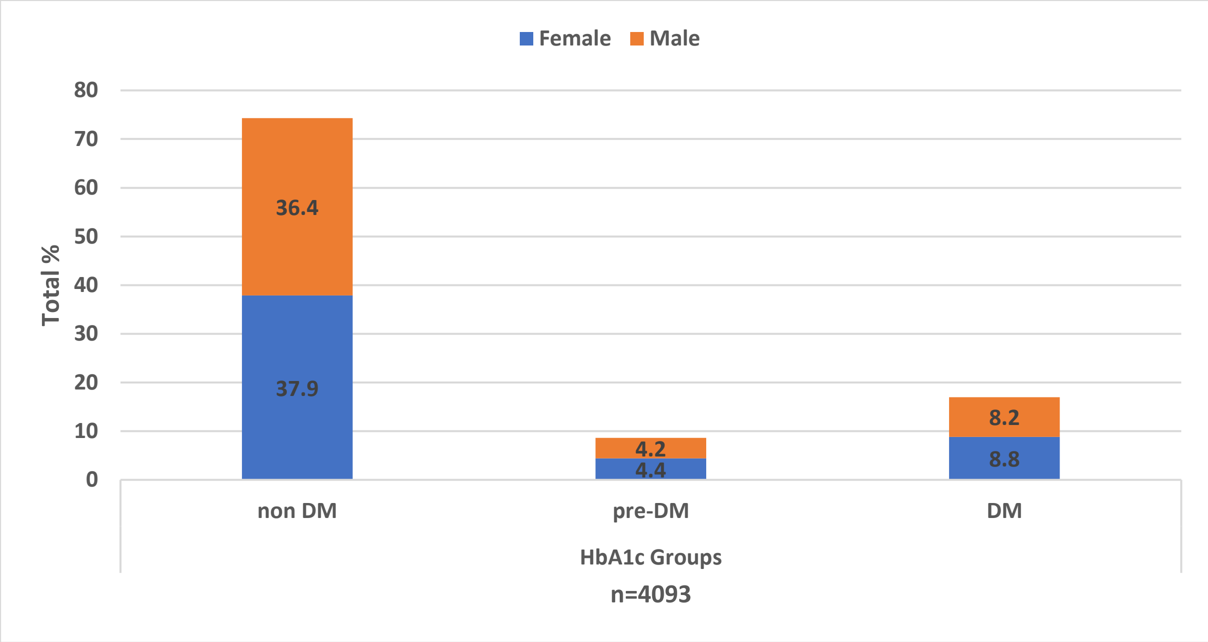

Figure 5.7: Secondary data distribution of HbA1c levels (excluding T2D) by sex

Secondary data sample distribution by Body Mass Index levels

BMI distribution by age group is shown in Figure 5.8. BMI levels increase with age peaking in the overweight (9.4%) and obese (9.5%) levels in the age group 30-39 years. After that, the proportion of obese and overweight continues to be higher than the normal weight throughout the following age groups. Participants who are underweight (BMI<18.5) are most numerous in the age group 18-29 (2.2%). After that, the proportions for underweight participants decreases as the sample gets older.

The BMI distribution pattern within the age groups suggests that there is an increase in the imbalance of energy intake and expenditure as the population becomes older. This may be explained by a decrease in the basal metabolic rate in later life (144).

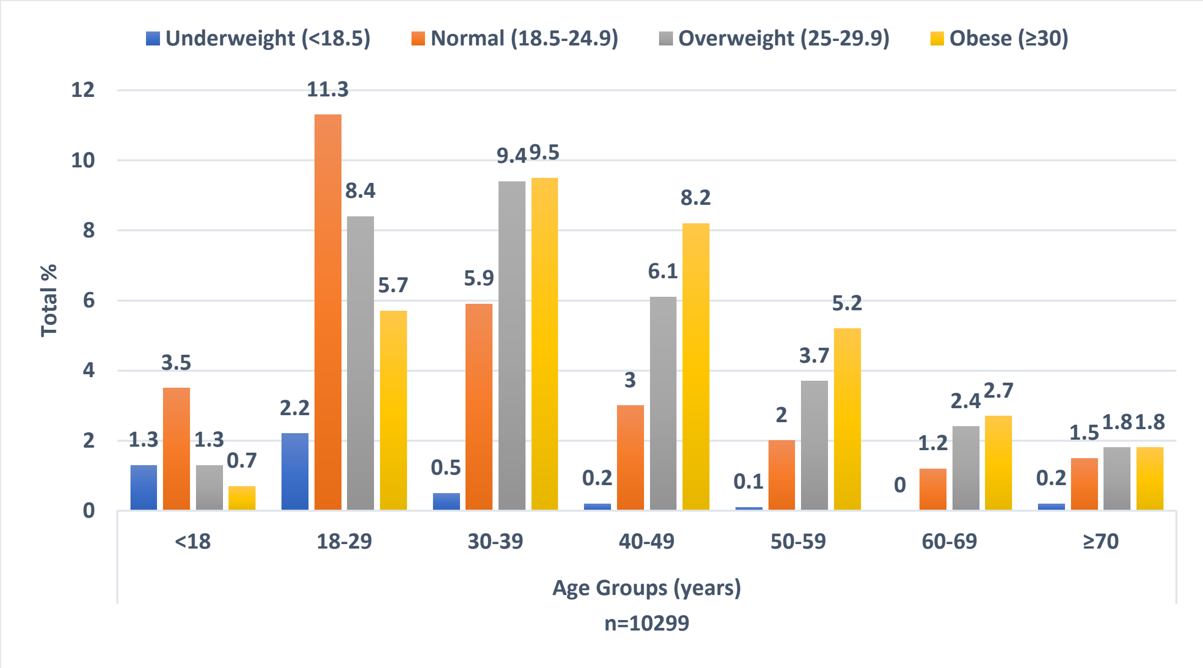

Figure 5.8: Secondary data distribution for BMI by age group

BMI distribution by sex can be seen in Figure 5.9. Obese participants (BMI>30) total 34% and more of them are females. The overweight participants total 33% and more of them are males.

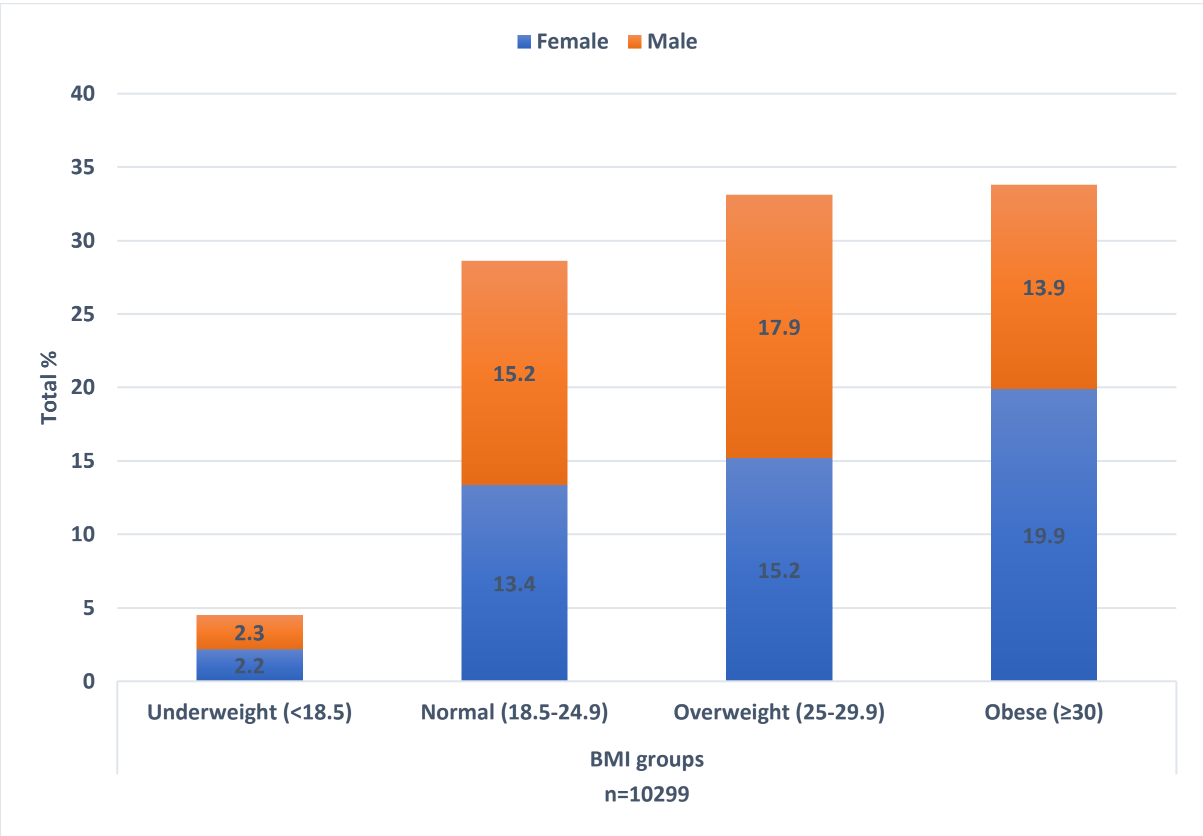

Figure 5.9: Secondary data distribution for BMI by sex

Secondary data sample distribution by Households monthly income estimates in Saudi Riyals

Figures 5.10 and 5.11 show the distribution for the estimated household monthly income (as a measure for socioeconomic status) among the age groups. All age groups have similar patterns of distribution for the income level within them with a pattern showing a decrease in income levels as age increases. Distribution of the income estimates by sex shows that males have higher income level distribution in general within the secondary data sample.

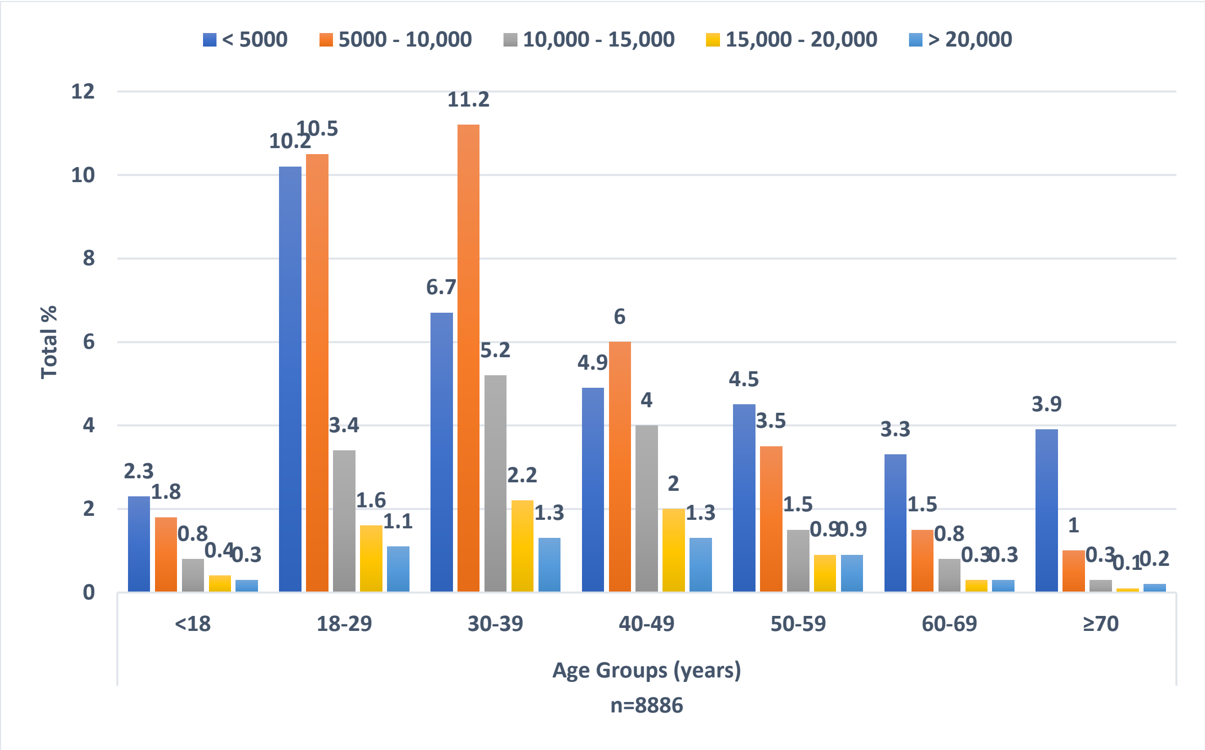

Figure 5.10: Secondary data distribution for household monthly income estimates (Saudi Riyals) by age group

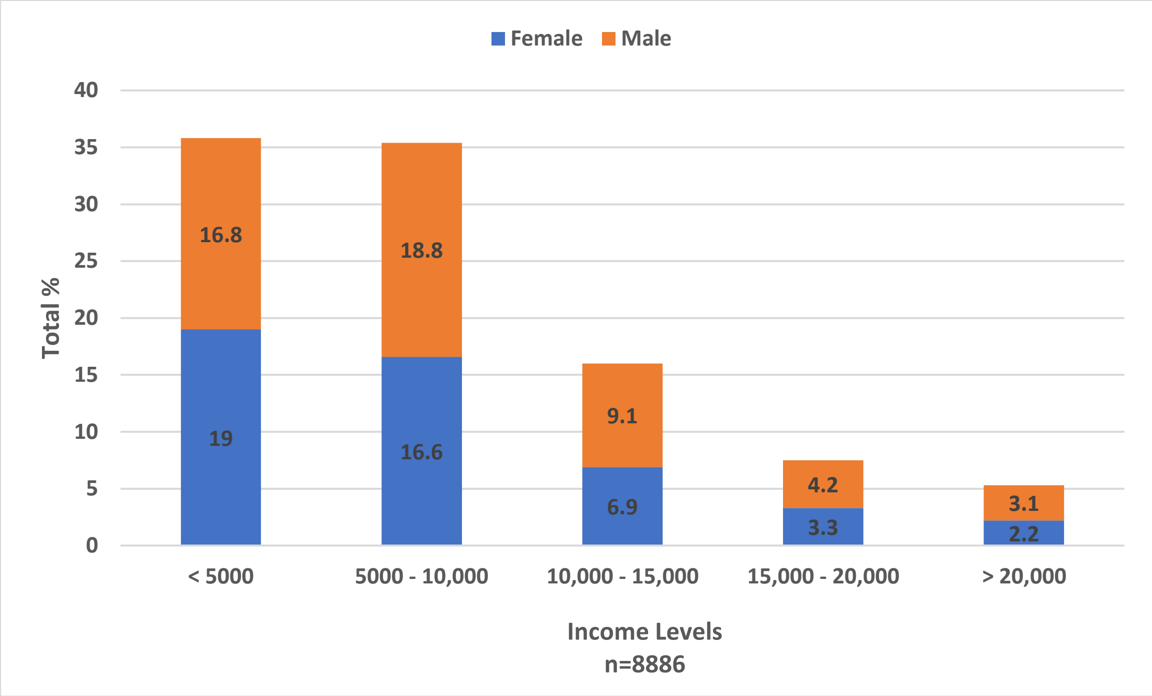

Figure 5.11: Secondary data distribution for income level by sex

Secondary data sample distribution by Education levels

Distribution of the secondary data sample for education level by age group and sex can be seen in Figure 5.12 and Figure 5.13. In general, the education levels are higher in the younger generations for the secondary data sample compared to the older ones. Regarding sex, males have slightly higher numbers for higher levels of education compared to females.

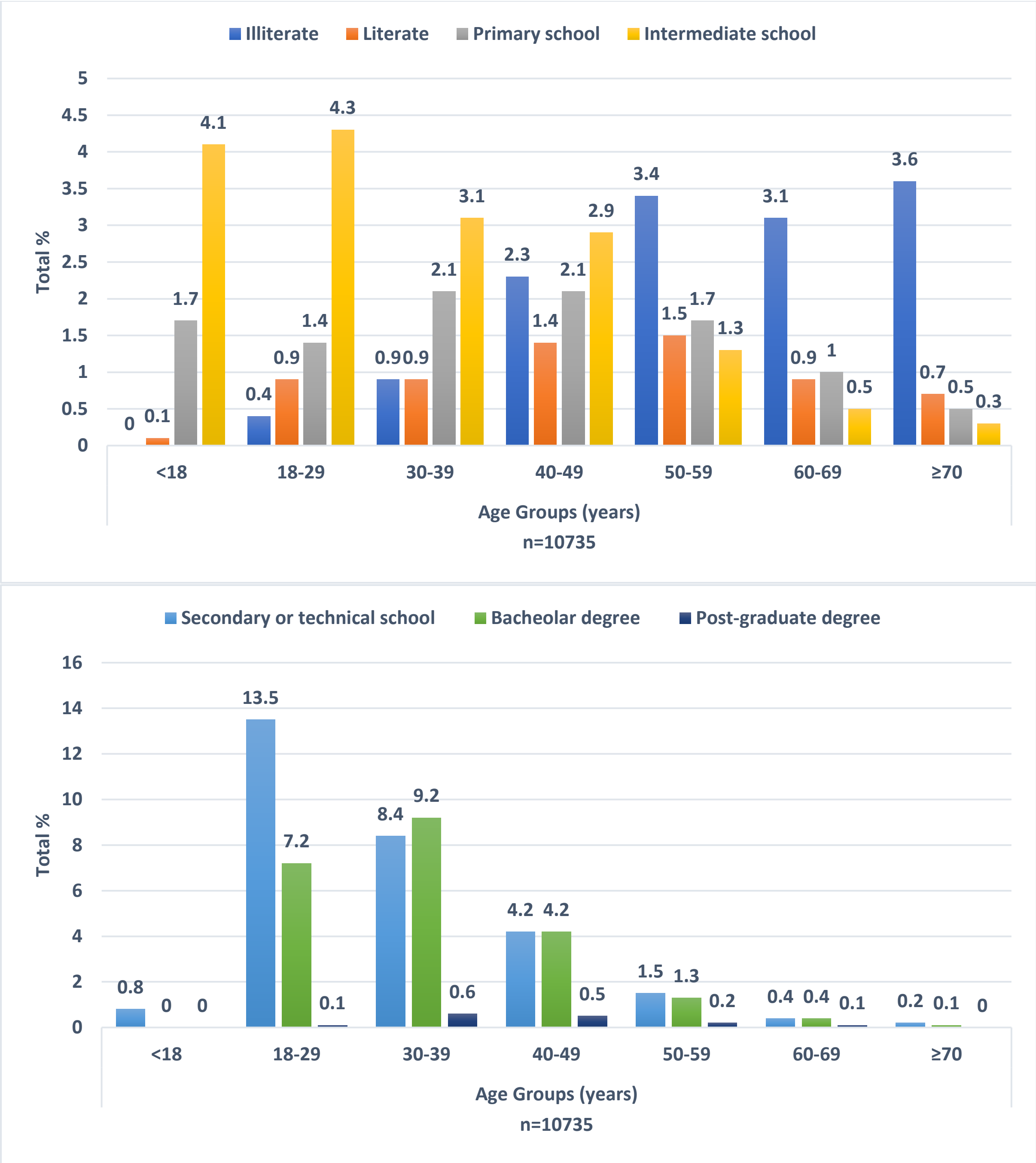

Figure 5.12: Secondary data distribution for education level by age group

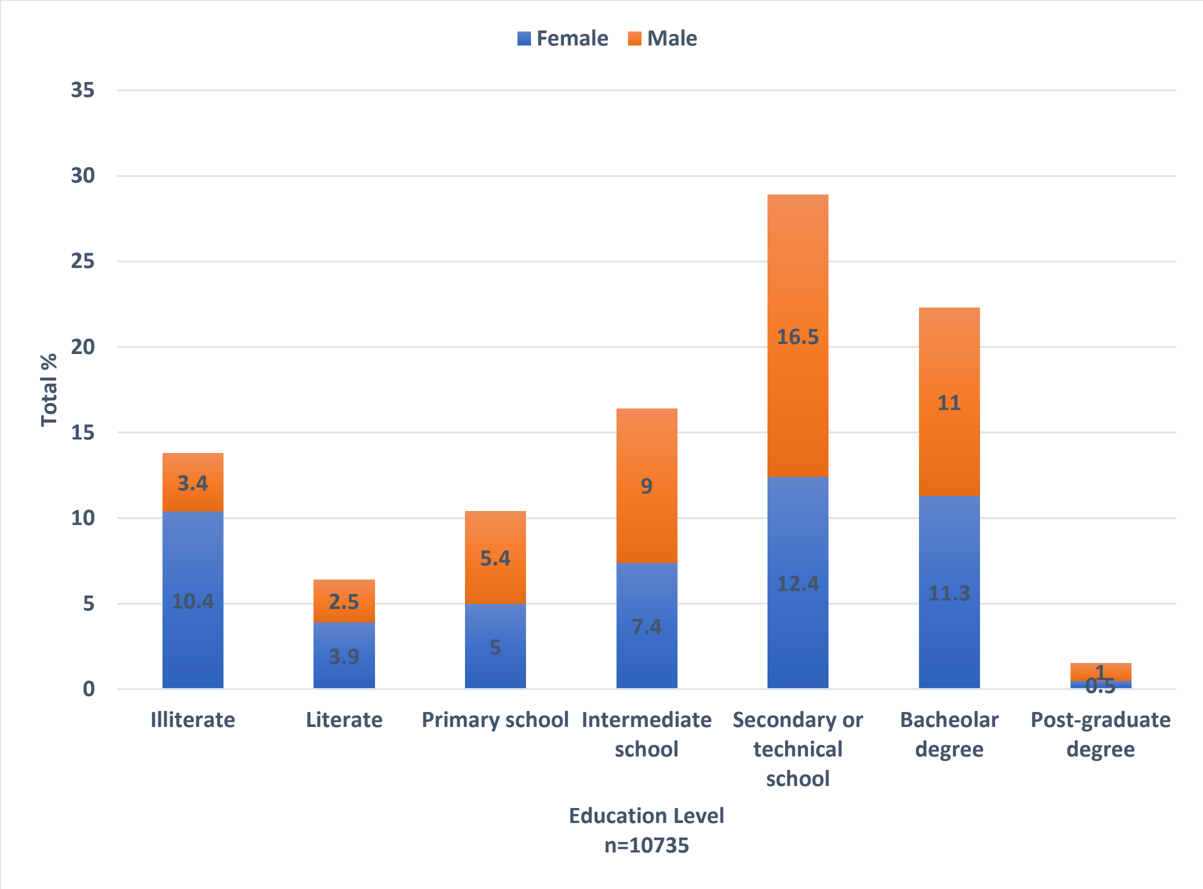

Figure 5.13: Secondary data distribution for education level by sex

Secondary data sample distribution by Smoking status

The smoking status distribution by age group shows that smoking is highest in the age group 30-39 years followed by the age group 18-29 years within the secondary data sample (Figure 5.14). After the age of 39 years, smoking prevalence started to decline as the study sample grows older. Moreover, smoking is markedly more common in males than females within the secondary data sample (Figure 5.15).

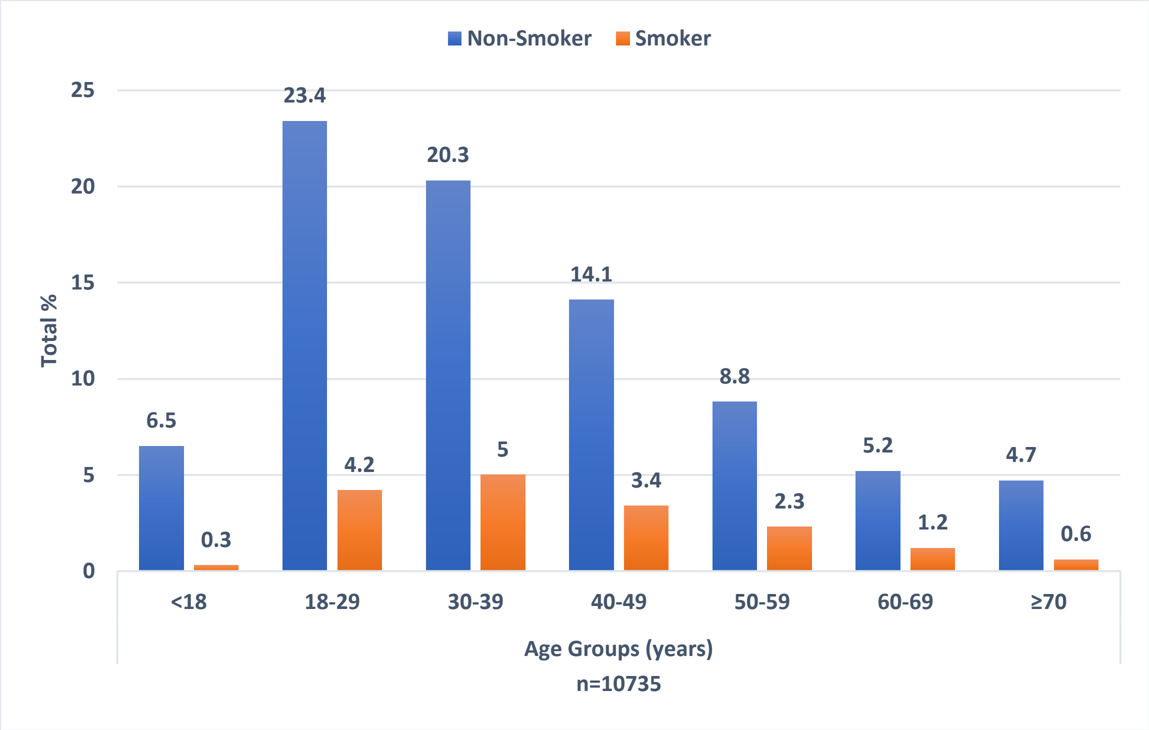

Figure 5.14: Secondary data distribution for smoking status by age group

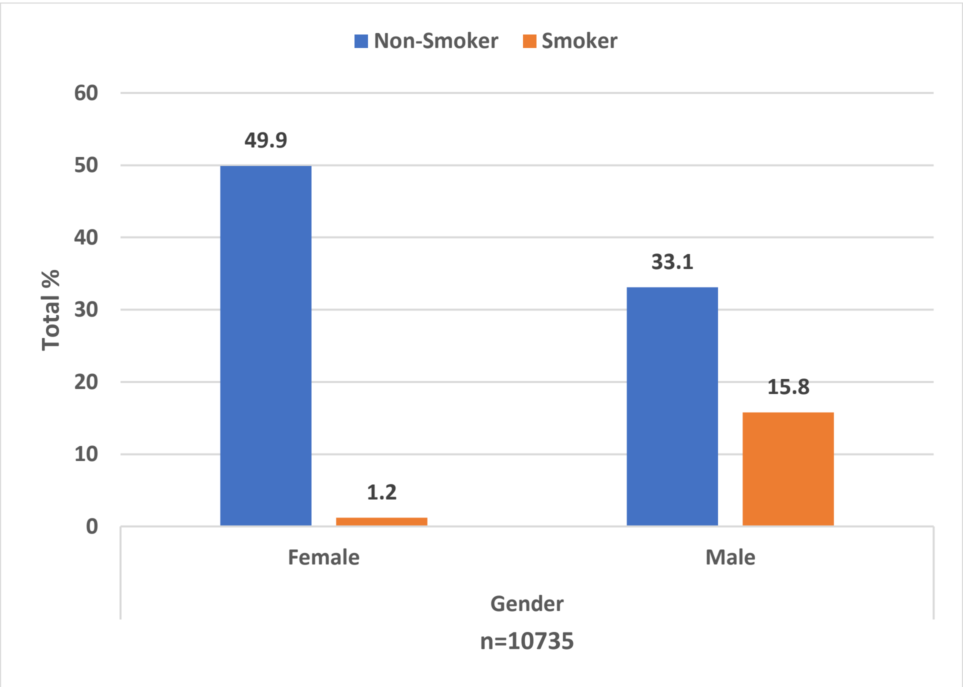

Figure 5.15: Secondary data distribution for smoking status by sex

Secondary data sample distribution by Physical activity

The physical activity distribution by age group and sex shows that the younger age groups and males have the highest levels of physical activity (Figures 5.16 and 5.17). It also shows that at ages above 49 years, there is a considerable decrease in the levels of physical activity.

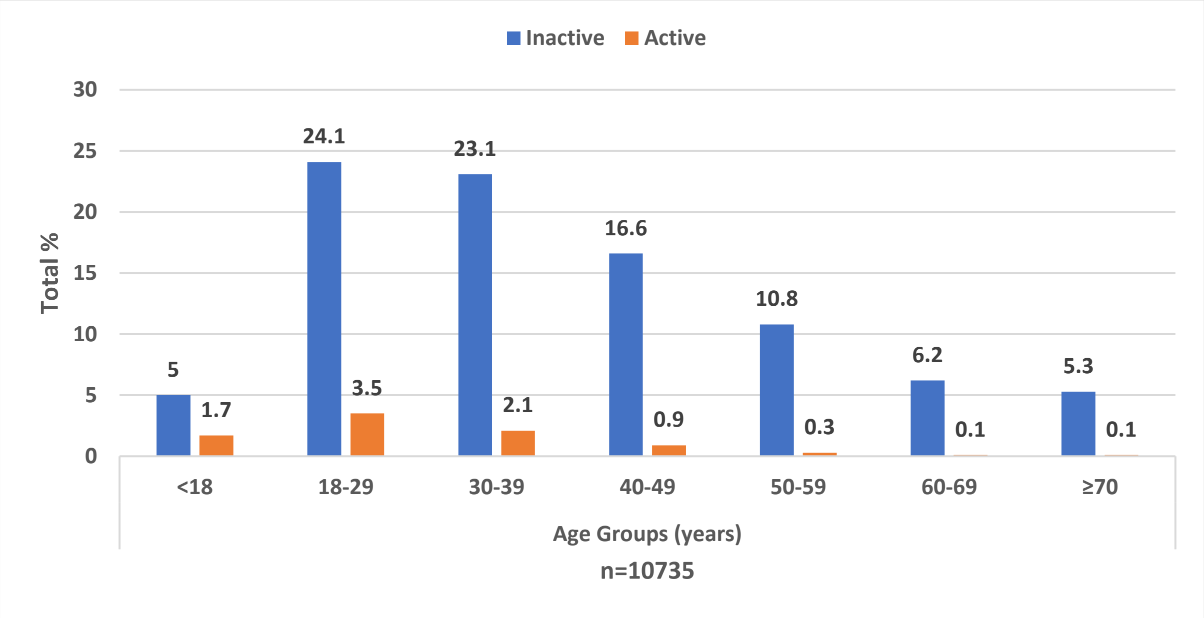

Figure 5.16: Secondary data distribution for physical activity by age group

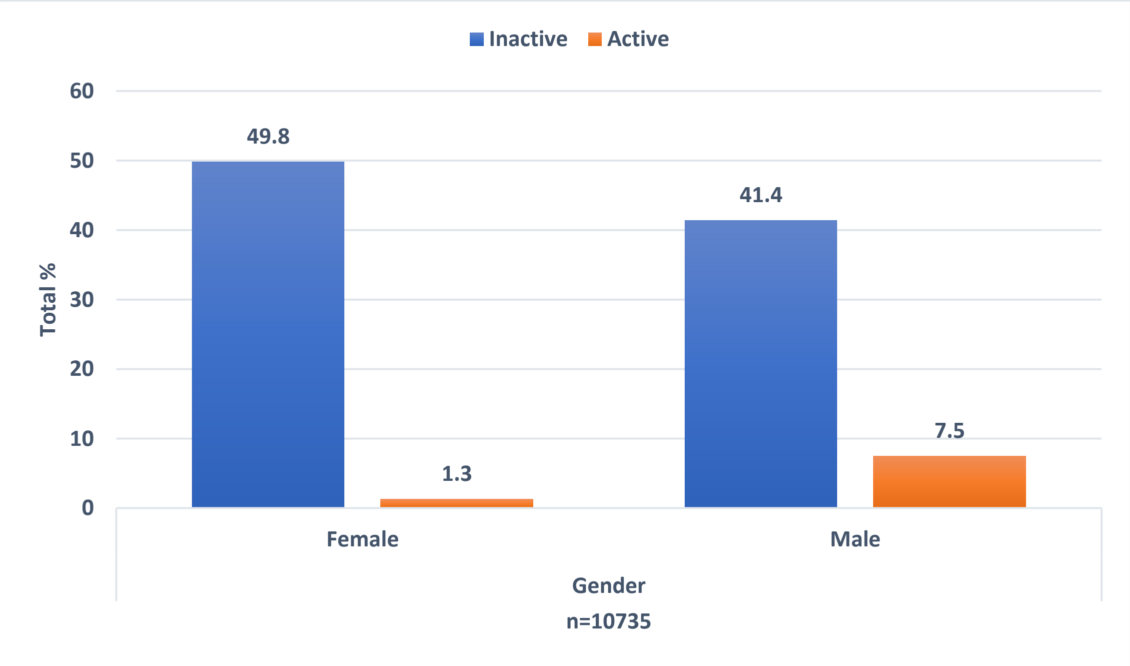

Figure 5.17: Secondary data distribution for exercising regularly by sex

Secondary data sample distribution by having Medical history of coronary heart diseases (CHD)

The distribution for having coronary heart diseases (CHD) by age group and sex shows a low prevalence (less than 1%) within the secondary data sample (Figure 5-18). Females and males reported having a similar history of chronic heart disease within the secondary data sample (Figure 5-19).

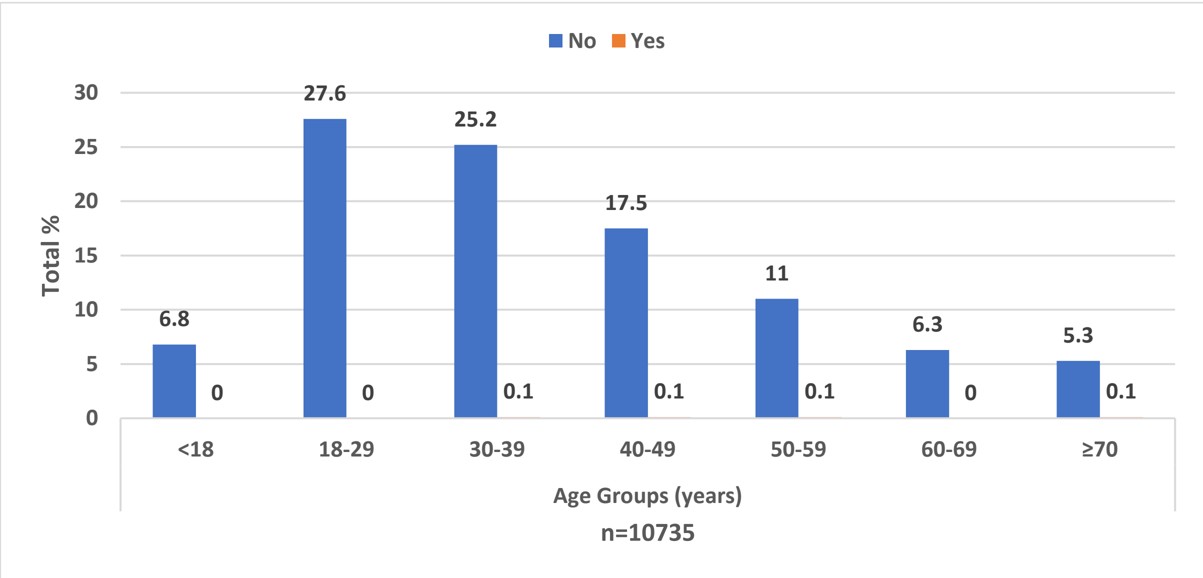

Figure 5.18: Secondary data distribution for having a history of cardiovascular disease by age group

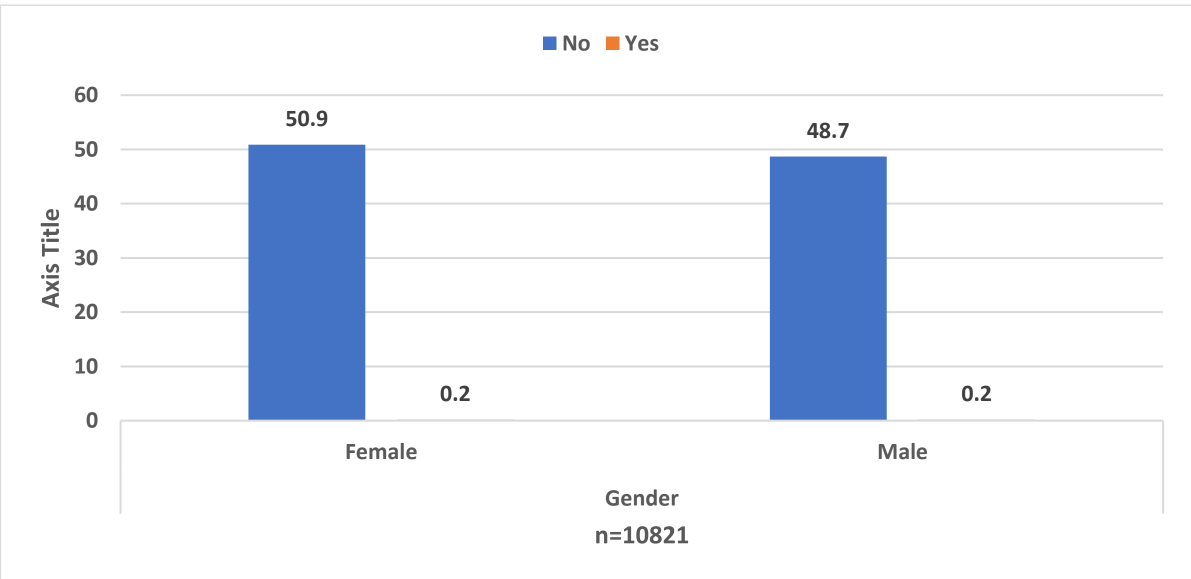

Figure 5.19: Secondary data distribution for having a history of cardiovascular disease by sex

Secondary data sample distribution by Having a family history of T2D

The distribution for having a family history of T2D by age group and sex shows a normal distribution that peaks at the age 50-59 years (Figure 5.20). Most participants reported having a family history of T2D regardless of sex (Figure 5.21).

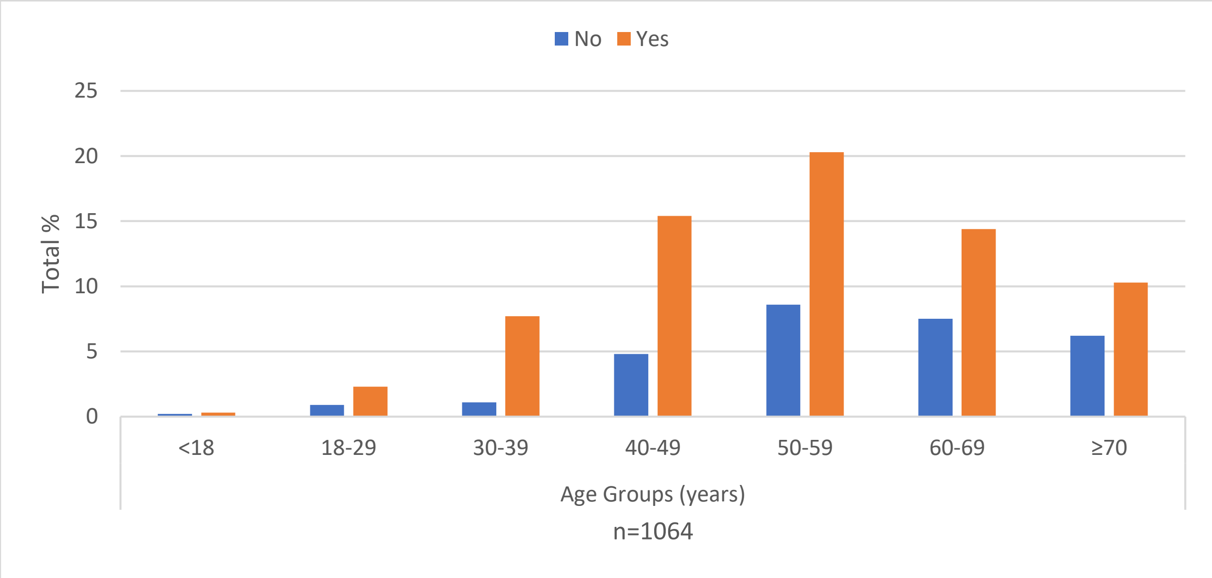

Figure 5.20: Secondary data distribution for having a family history of T2D by age group

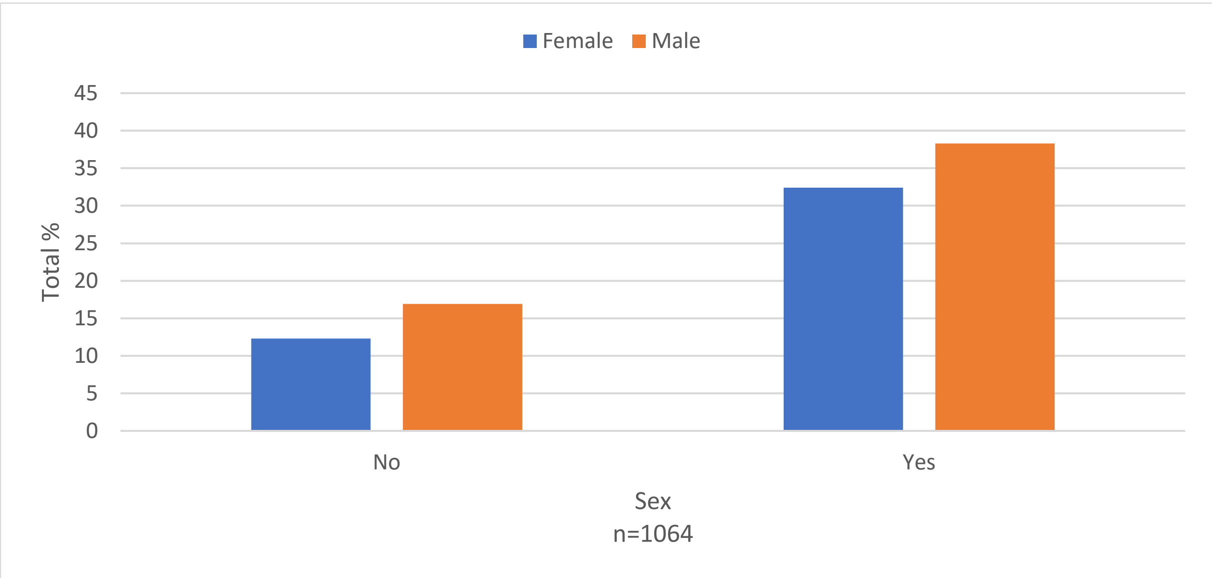

Figure 5.21: Secondary data distribution for having a family history of T2D by sex

Secondary data FFQ distribution by Age groups

Figure 5.44 shows the mean frequency of consumption of food items per day stratified by age group. The younger age groups of 18 years or less and 18-29 years had higher proportions for consuming carbonated drinks, cheese, processed meat, processed foods and poultry than any other age group. In contrast, the most frequently consumed drink by those who are in the 70 or older age group is milk. Vegetables are frequently consumed by all age groups while shrimp and processed meat continue to be the lowest consumed items within each age group as seen in the main patterns of distribution of food items in Figure 5.35.

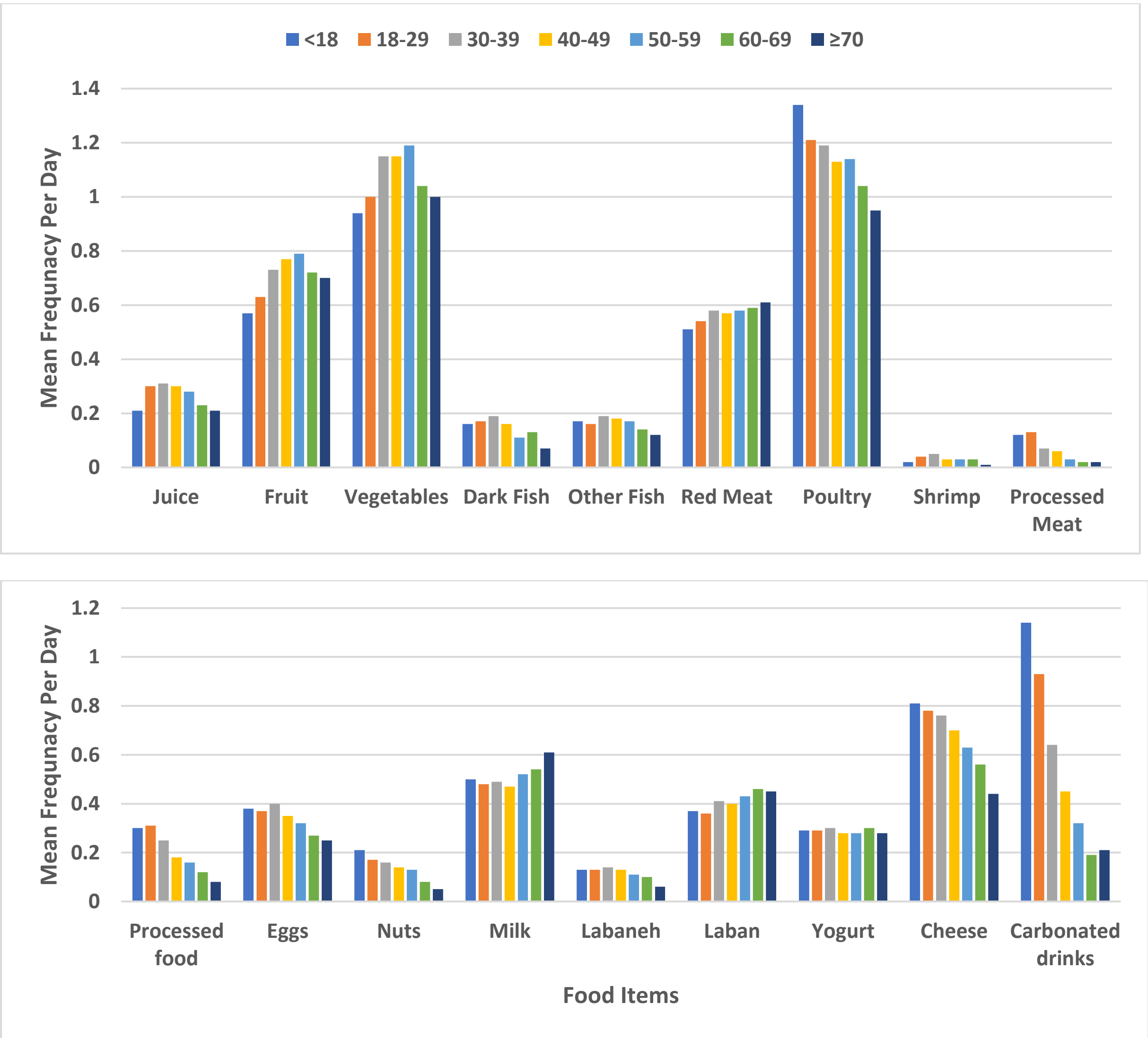

Figure 5.44: Mean frequency of consumption per day of the food items FFQ of the secondary data by age group

Secondary data FFQ distribution by Sex

Regarding food items mean frequency of consumption stratified by sex, the distribution shows that males consume more daily red meat, poultry and carbonated drinks daily than females (Figure 5.45). Mean daily frequency of consumption of other food items appears to be closely similar in general for both females and males (Figure 5.45).

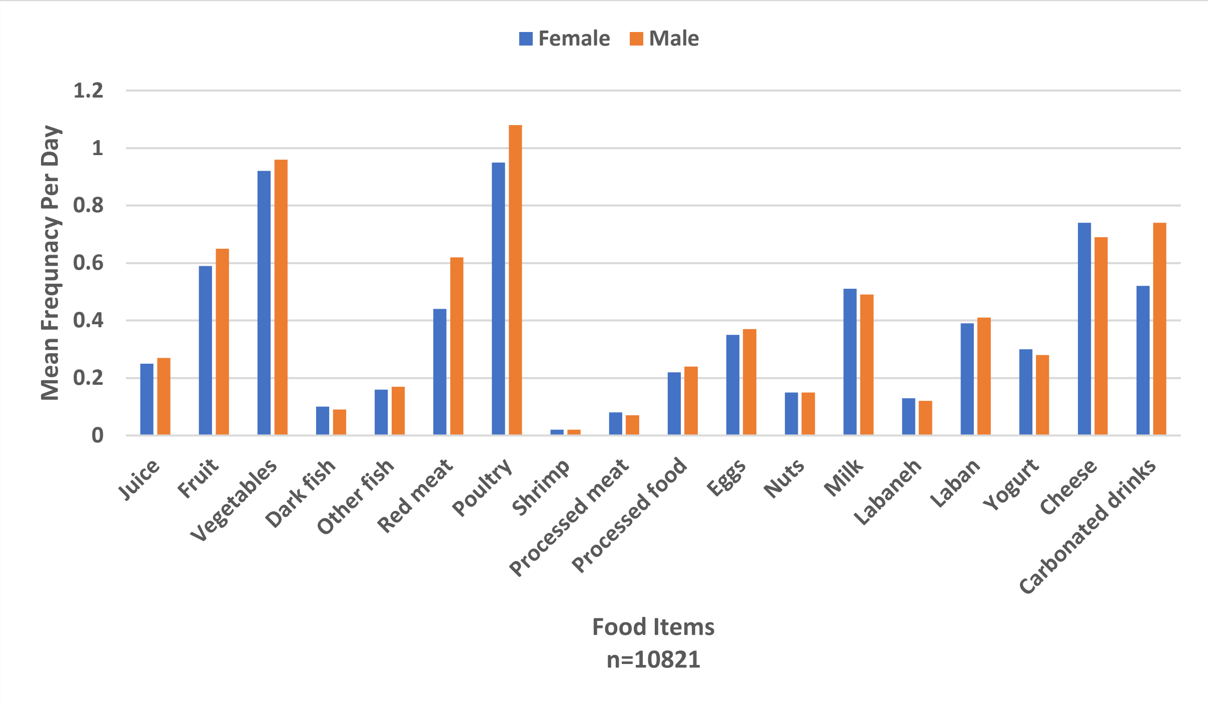

Figure 5.45: Mean frequency of consumption per day of the food items FFQ of the secondary data by sex

Secondary data FFQ distribution by Diagnosis groups

The mean frequency of daily consumption of the single food items stratified by the diagnosis groups can be seen in Figure 5.46. The only noticeable feature in comparison with the main distribution in Figure 5.43 is that those with diagnosed T2D report that they consume fewer carbonated drinks; however, there is no other change in the diet compared to the main distribution for those with diagnosed T2D. There might be other changes in diet for those diagnosed with T2D, which cannot be seen here given the fact that the secondary data FFQ contained only 18 broad categories of food items.

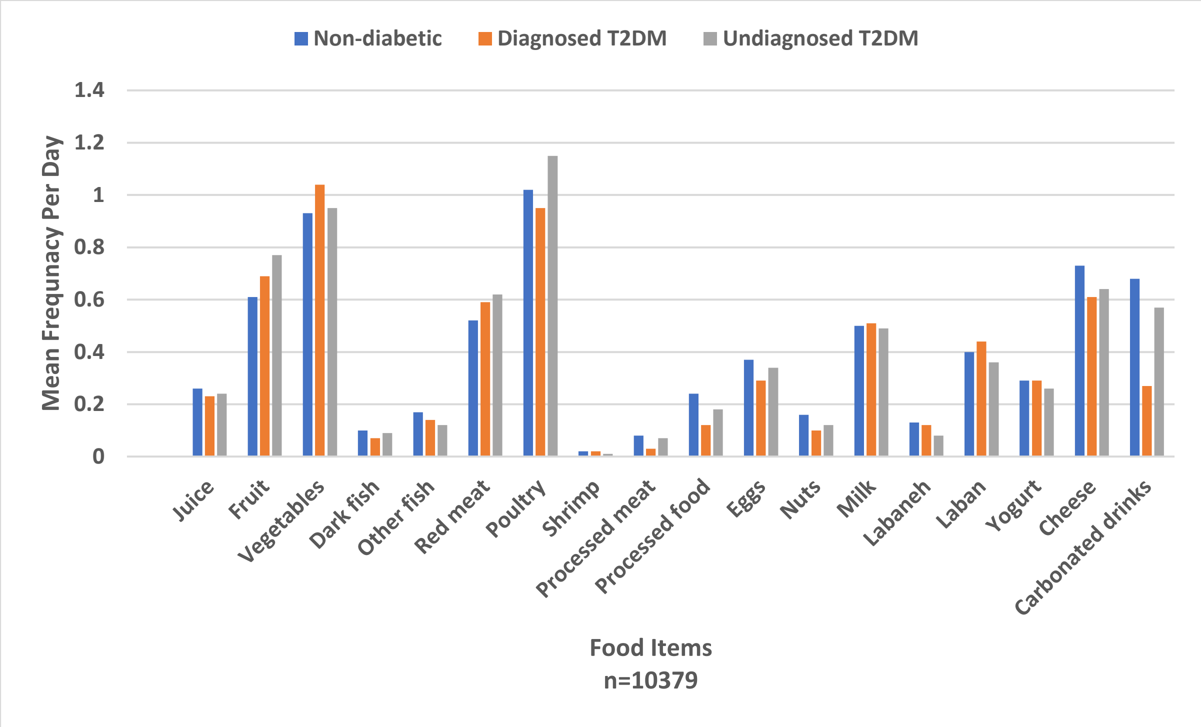

Figure 5.46: Mean frequency of consumption per day of the food items FFQ of the secondary data by diagnosis group

Secondary data FFQ distribution by HbA1c levels

Daily consumption frequencies of the single food items stratified by HbA1c diagnosis groups follow a similar distribution to the mean distribution found in Figure 5.43 (Figure 5.47). This suggests the possibility that individuals, in general, do not change their diet significantly after receiving a diagnosis of diabetes. This can also be due to the limited number of food items included and broad categories used for data collection, which means that the questionnaire is insufficiently sensitive to differences in diet in relation to a wider range of single food items.

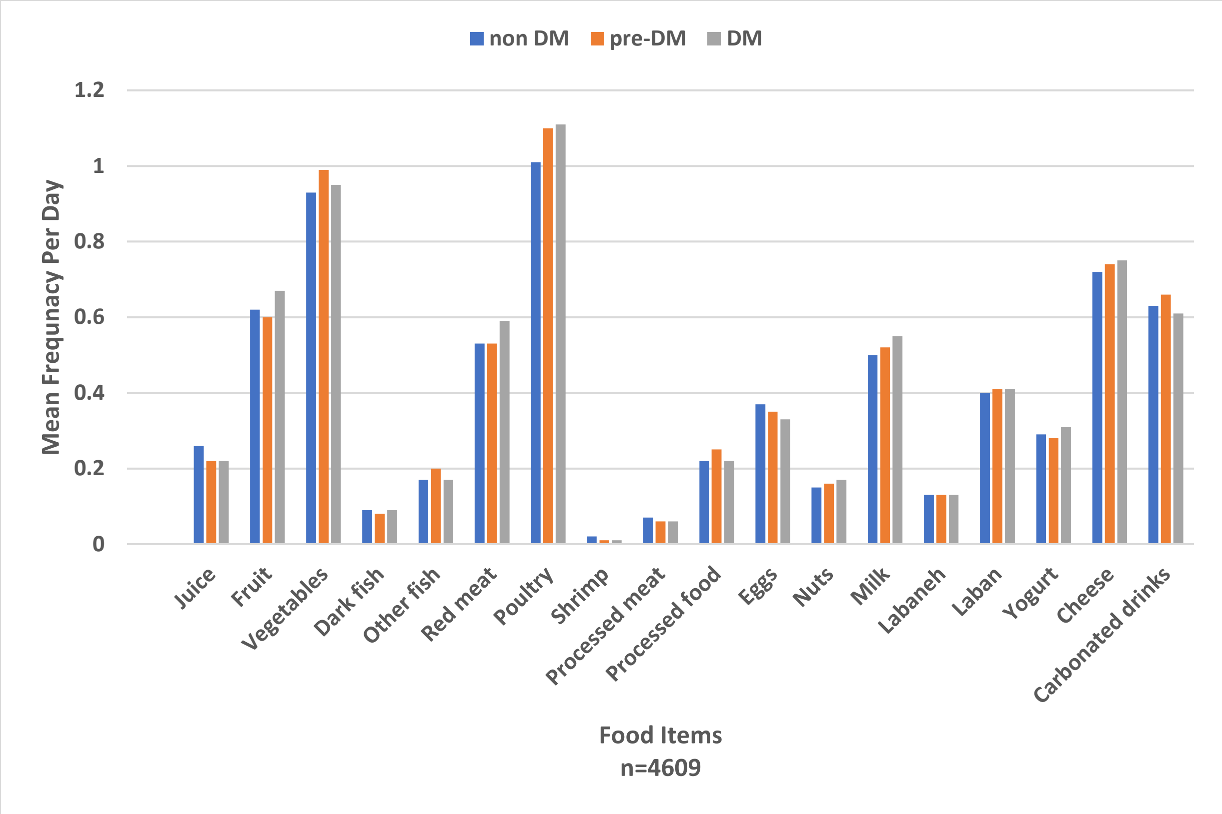

Figure 5.47: Mean frequency of consumption per day of the food items FFQ of the secondary data by HbA1c level

Secondary data FFQ distribution by HbA1c levels (excluding diagnosed T2D)

After excluding those with T2D diagnoses, the distribution of the mean daily frequency of the secondary data single food items stratified by HbA1c diagnosis groups can be seen in Figure 5.48. There is no apparent change in the pattern of the diets compared to not excluding those diagnosed with T2D.

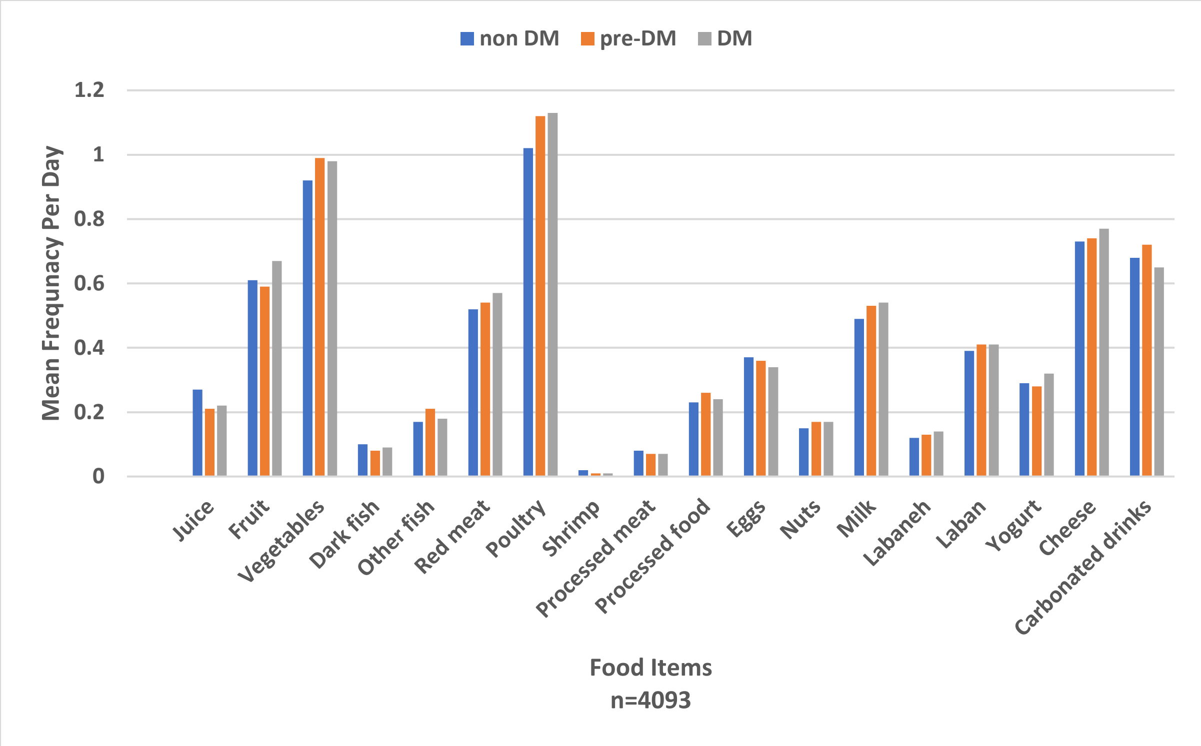

Figure 5.48: Mean frequency of consumption per day of the food items FFQ of the secondary data by HbA1c group (excluding diagnosed HbA1c)

Secondary data FFQ distribution by Body Mass Index levels

The mean frequency of consumption of the secondary data food items by BMI level shows an increase in the consumption of vegetables, fruits and red meat as the BMI level for participants increases (Figure 5.49). In contrast, there is a decrease in the daily frequency of consumption of cheeses and carbonated drinks as BMI level increases among participants.

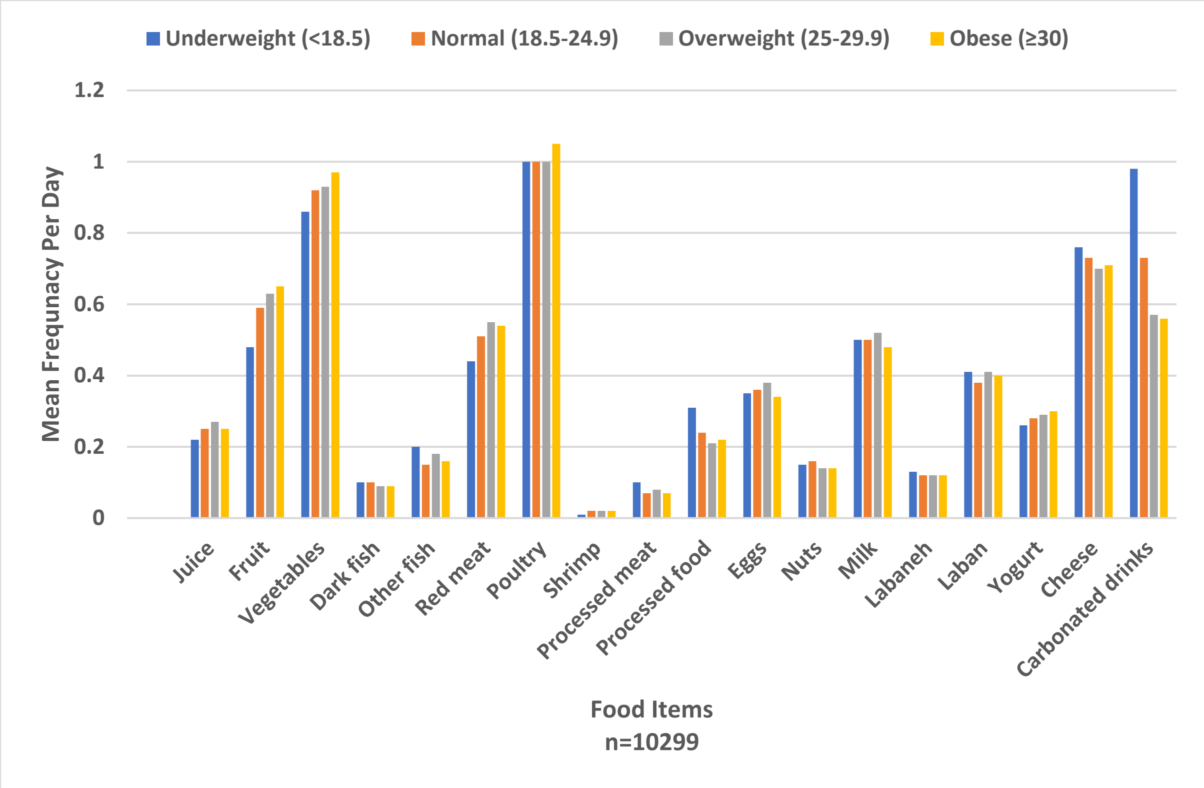

Figure 5.49: Mean frequency of consumption per day of the food items FFQ of the secondary data by BMI group

Secondary data FFQ distribution by Income levels

Level of household monthly income can be used to examine the food frequencies by socioeconomic status. Figure 5.50 shows the mean daily frequency of consumption of the single food items stratified by the household monthly income estimates. The only noticeable difference compared to the main pattern seen in figure 5.43, is that those with the highest income levels (more than 20,000 Riyals per month) consumed more milk and cheeses in comparison with those in other levels of income.

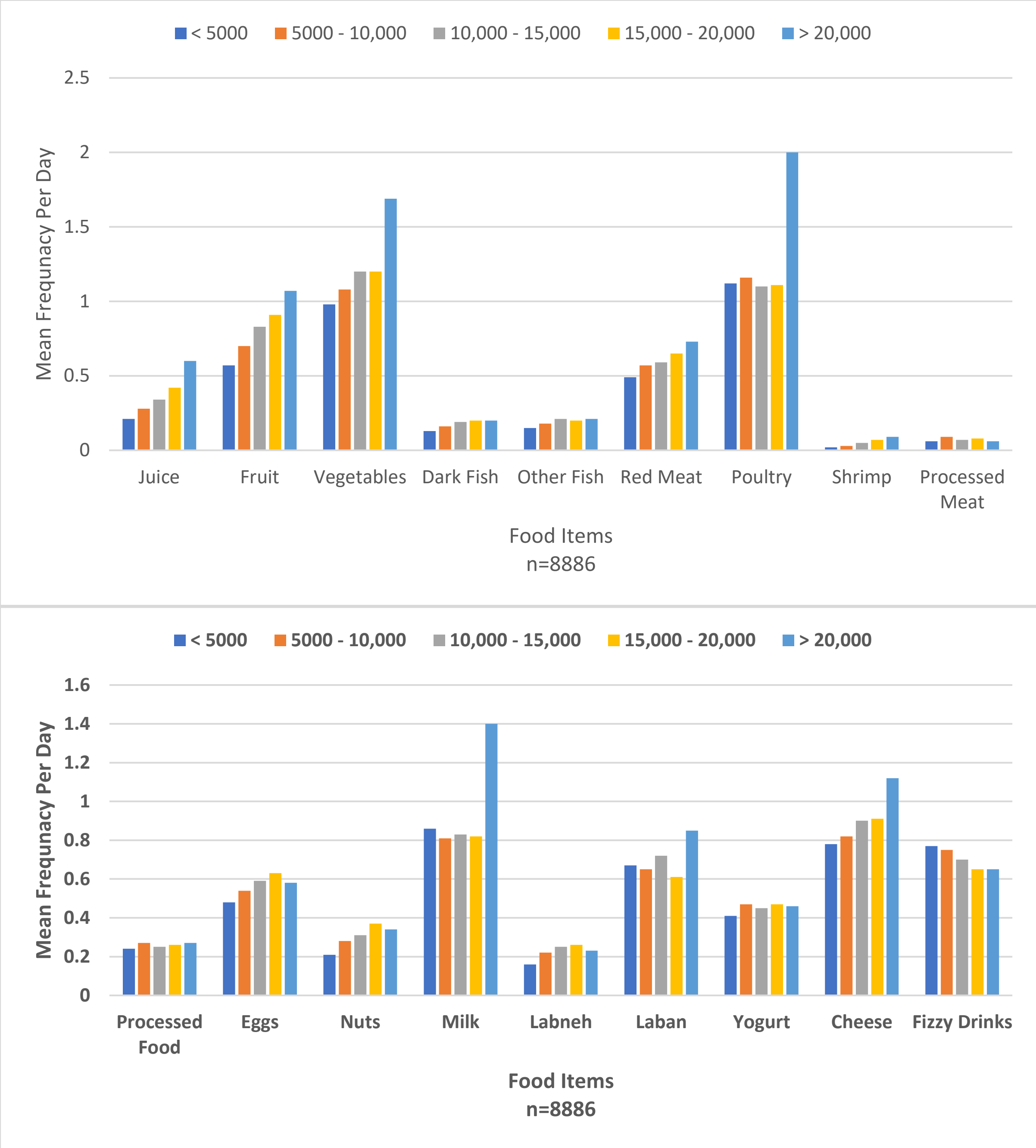

Figure 5.50: Mean frequency of consumption per day of the food items FFQ of the secondary data by

Secondary data FFQ distribution by Education levels

The distribution of the mean daily frequency of consumption of the single food items stratified by education levels can be seen in figure 5.51. It is noticeable that those with no school education consume fewer frequencies of carbonated drinks and more milk in comparison with the mean distribution seen in figure 5.43. Similar to the pattern seen for the highest income level seen in figure 5.50, those with the highest education level (post-graduate degrees) consumes more milk and cheese in comparison with the main distribution pattern seen in figure 5.43.

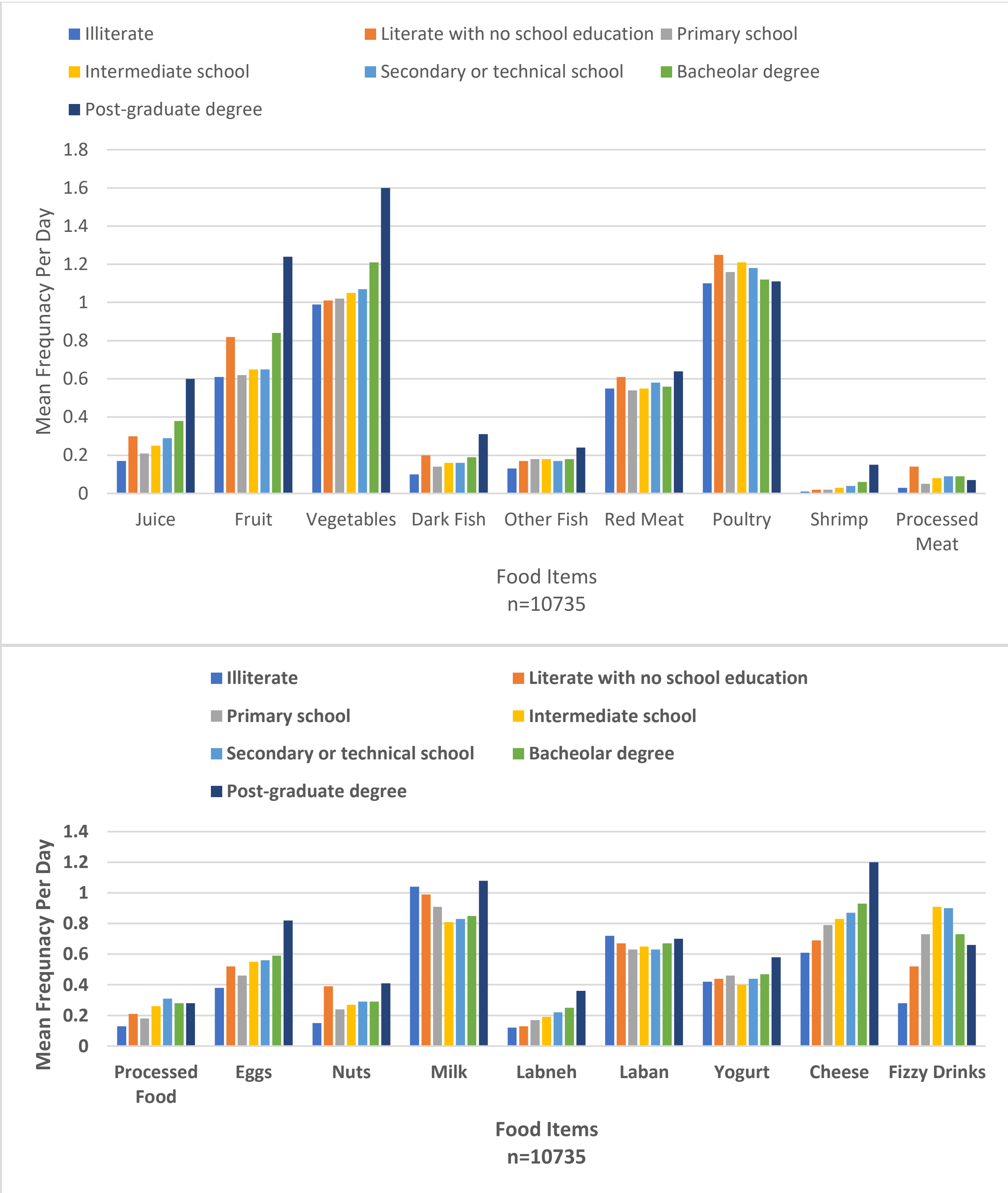

Figure 5.51: Mean frequency of consumption per day of the food items FFQ of the secondary data by

Secondary data FFQ distribution by Smoking status

Figure 5.52 shows the distribution of the mean daily frequency of consumption of the single food items stratified by smoking status. It appears that both smokers and non-smokers have similar consumption of most common food items.

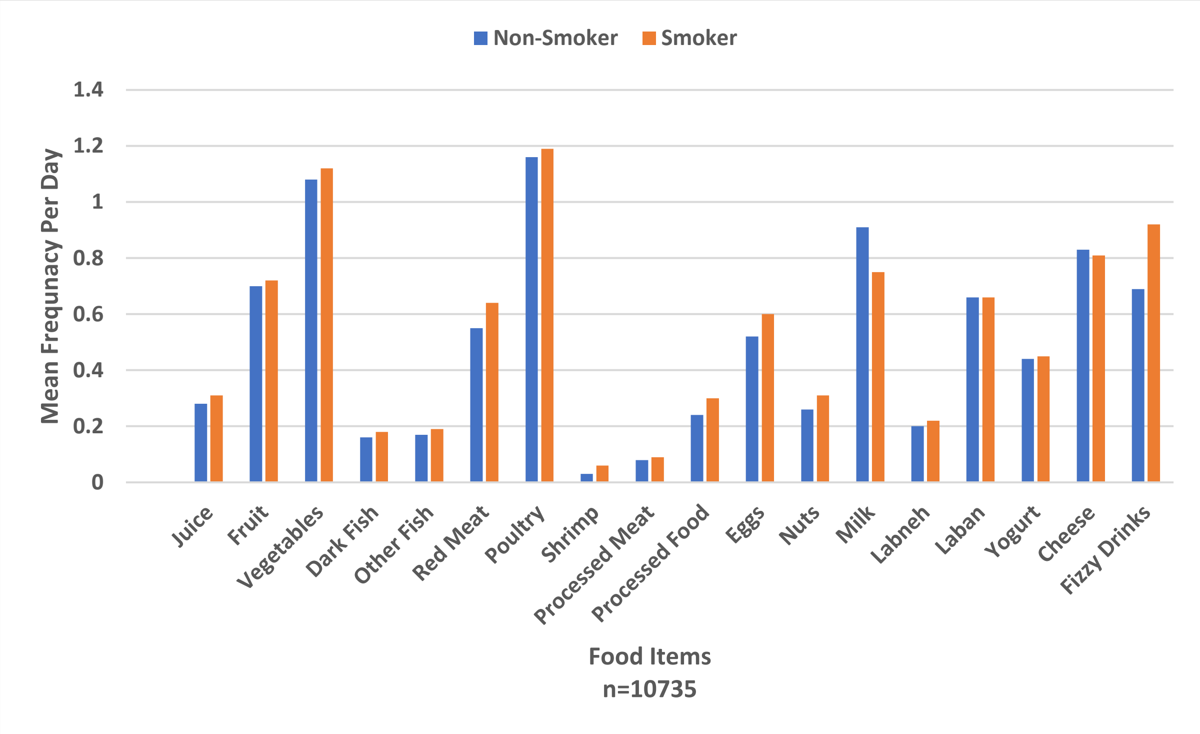

Figure 5.52: Mean frequency of consumption per day of the food items FFQ of the secondary data by smoking status

Secondary data FFQ distribution by Physical activities

The distribution of the mean daily frequency of consumption of the single food items stratified by physical activity can be seen in figure 5.53.

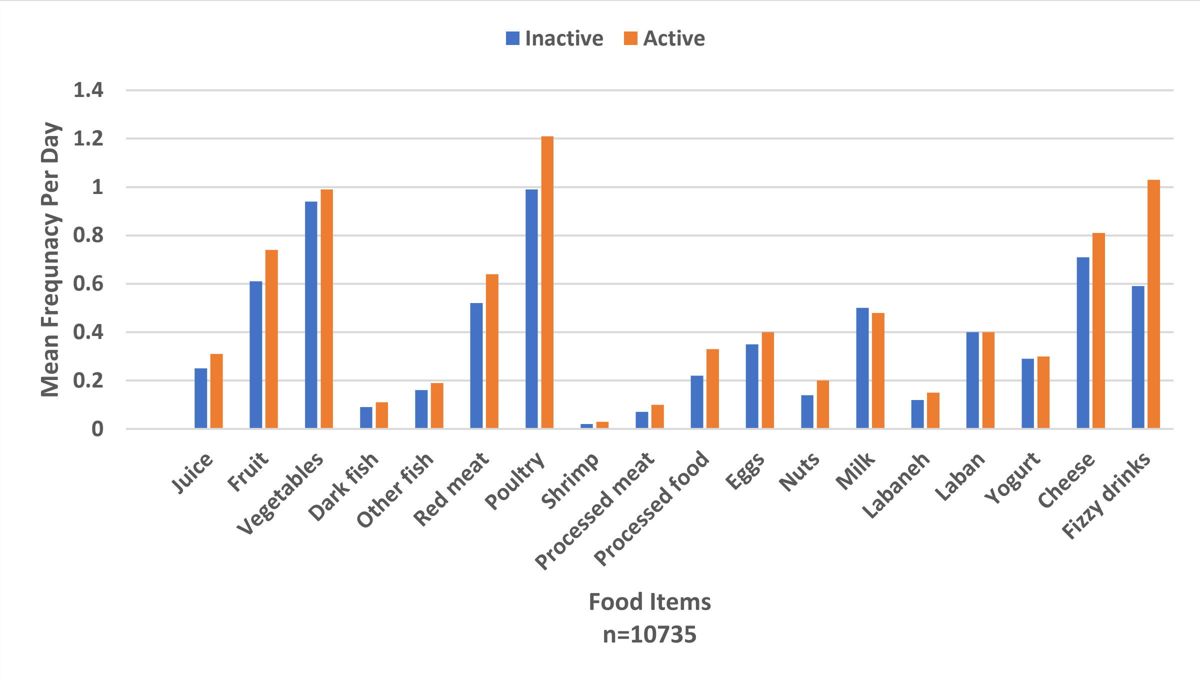

Figure 5.53: Mean frequency of consumption per day of the food items FFQ of the secondary data by physical activity

Secondary data FFQ distribution by Having a history of cardiovascular disease

The distribution of the mean daily frequency of consumption by reporting having a history of cardiovascular diseases can be seen in figure 5.54. Those who reported having a history of cardiovascular diseases appears to consume more laban and processed meat compared to the main distribution seen in figure 5.43.

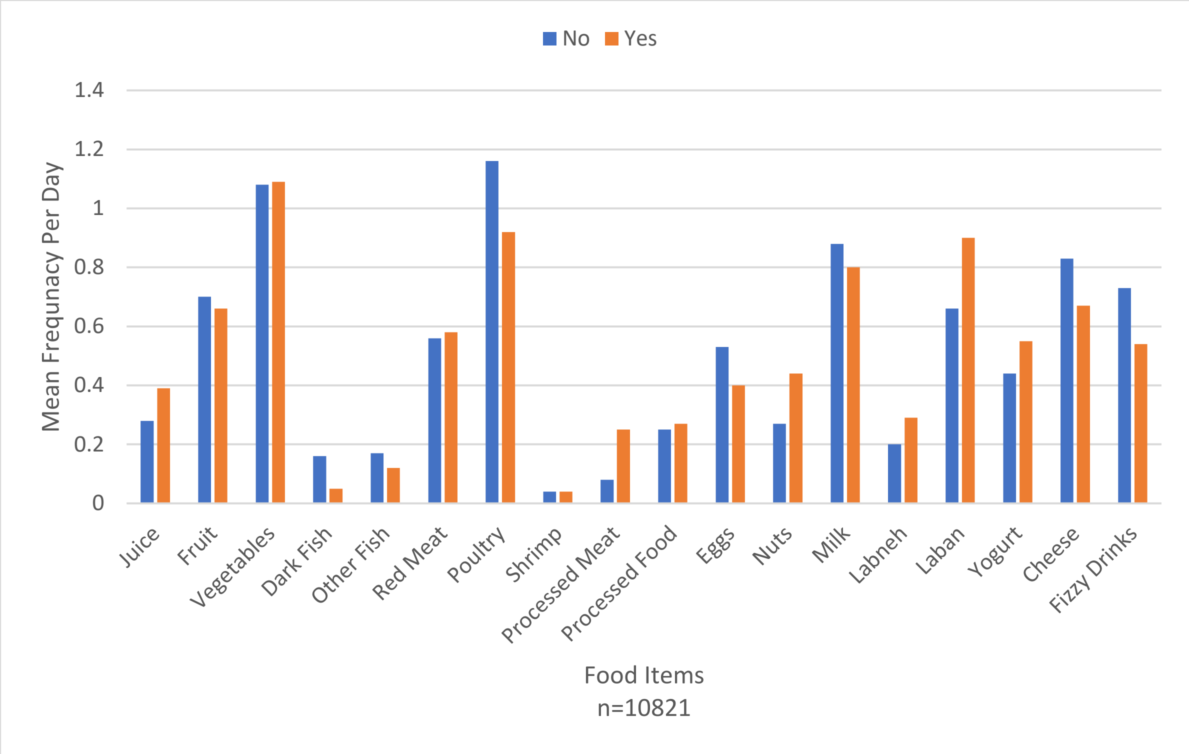

Figure 5.54: Mean frequency of consumption per day of the food items FFQ of the secondary data by the presence of cardiovascular disease

Secondary data dietary patterns association with household monthly income estimates

Figure 5.31 and Table 5.14 show the distribution for the secondary data dietary pattern scores by household monthly income estimate. Participants with a monthly income estimated to be more than 20,000 Saudi Riyals scored highest for the Traditional, Dairy Products and Fast Food dietary patterns (Figure 5.77 and Table 5.14). ANOVA hypothesis testing shows that there is a difference between different income levels in all the dietary patterns (Table 5.14). Table 5.15 displays the Bonferroni post hoc tests in which there are multiple differences with most of them between the participants who had income levels less than 10,000 Saudi Riyals per month and other income levels.

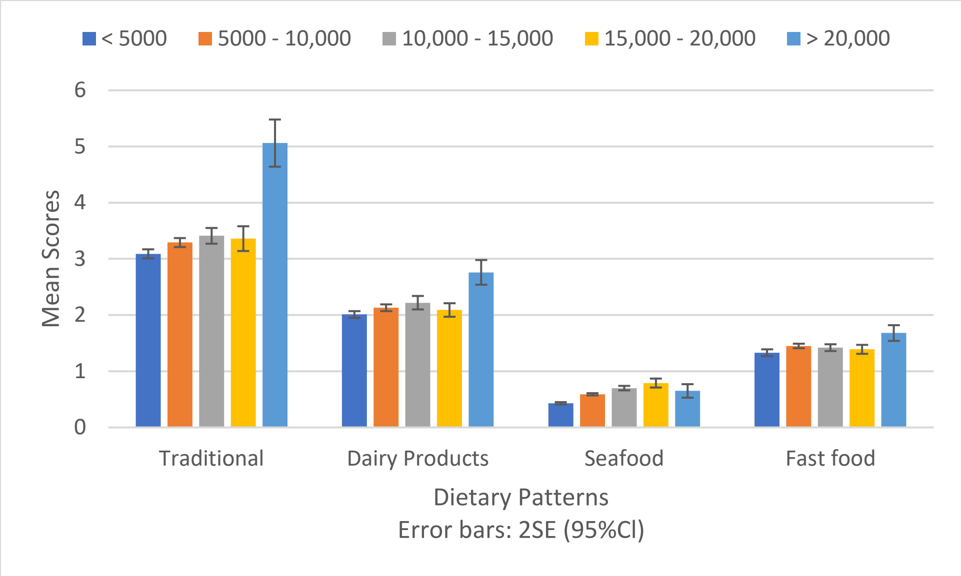

Figure 5.31: Secondary data mean dietary pattern scores stratified by household estimated monthly income level in Saudi Riyals

Table 5.14: Secondary data dietary pattern score means, standard deviations and ANOVA hypothesis tests stratified by household estimated monthly income level in Saudi Riyals

	Traditional		**Dairy Products**		**Seafood**		**Fast Food**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
< **5000**	3.09	2.24	2.01	1.7	0.43	0.68	1.33	1.33
5000 - 10,000	3.29	2.1	2.13	1.52	0.59	0.68	1.45	1.24
10,000 - 15,000	3.41	2.42	2.22	1.85	0.7	0.71	1.42	1.11
15,000 - 20,000	3.36	2.36	2.09	1.38	0.79	0.79	1.39	0.99
> **20,000**	5.06	4	2.76	2.18	0.65	1.11	1.68	1.41
F* (p-value)	**57.043 (<0.001)**		**16.975 (<0.001)**		**47.111 (<0.001)**		**7.380 (<0.001)**	

* One way ANOVA hypothesis test

Table 5.15: Secondary data dietary pattern scores ANOVA post-hoc hypothesis tests for the in-between differences for estimated monthly household incomes in Saudi Riyals

Variable	Variables Compared to	Traditional	Dairy Products	Seafood	Fast Food
< 5000 (p-value)	**5000 - 10,000**	0.023	-	<0.001	0.008
	10,000 - 15,000	0.002	0.006	<0.001	-
	15,000 - 20,000	-	-	<0.001	-
	> 20,000	<0.001	<0.001	<0.001	<0.001
5000 - 10,000 (p-value)	**10,000 - 15,000**	-		<0.001	
	15,000 - 20,000	-	-	<0.001	
	> 20,000	<0.001	<0.001	-	0.012
10,000 - 15,000 (p-value)	**15,000 - 20,000**	-	-	-	-
	> 20,000	<0.001	<0.001	-	0.008
15,000 - 20,000 (p-value)	**> 20,000**	<0.001	-	-	0.008

*Only significant p-values are showing

Secondary data dietary patterns association with Education level

On examining the distribution for the primary data dietary pattern scores by participant education level, participants with post-graduate degrees scored highest for the Traditional, Dairy Products and Seafood dietary patterns (Figure 5.32 and Table 5.16). Since the Fast Food dietary pattern is common among the young age groups, it was also common among those with intermediate or secondary school level education.

ANOVA hypothesis test reveals that there are statistically significant differences in dietary pattern scores between all the education levels (Table 5.16).

For participants with different education levels, there were statistically significant differences in scores for the Fast Food and Seafood dietary patterns (Table 5.33). Table 5.34 displays the Bonferroni post hoc tests with most of the differences between the education level groups for the Seafood and Fast Food dietary patterns.

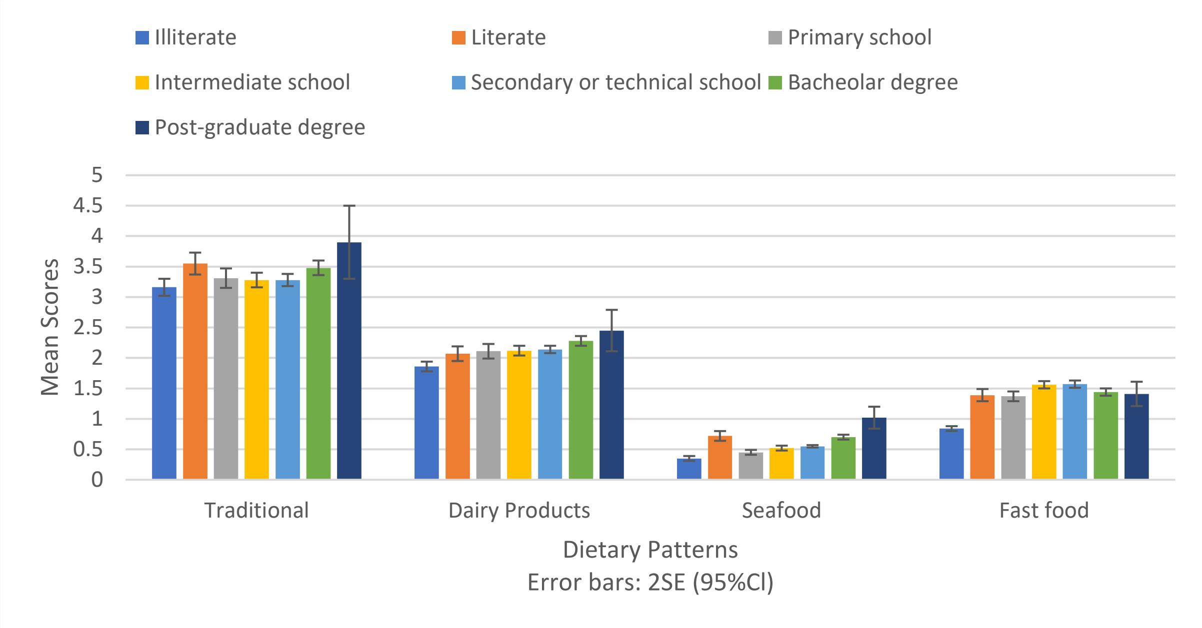

Figure 5.32: Secondary data mean dietary pattern scores stratified by participant education level

Table 5.16: Secondary data dietary pattern score means, standard deviations and ANOVA hypothesis tests stratified by participant education level

	Traditional		**Dairy Products**		**Seafood**		**Fast Food**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Illiterate	3.16	2.34	1.86	1.52	0.35	0.63	0.84	0.81
Literate (No school Education)	3.55	2.19	2.07	1.39	0.72	0.94	1.39	1.23
Primary school	3.31	2.42	2.11	1.69	0.45	0.67	1.37	1.24
Intermediate school	3.28	2.12	2.12	1.54	0.52	0.72	1.56	1.33
Secondary or technical school	3.28	2.38	2.14	1.64	0.55	0.69	1.57	1.35
Bachelor degree	3.48	2.46	2.28	1.8	0.7	0.73	1.44	1.19
Post-graduate degree	3.9	3.35	2.45	1.87	1.02	0.97	1.41	1.11
F (p-value)*	**4.607 (<0.001)**		**8.787 (<0.001)**		**46.481 (<0.001)**		**52.776 (<0.001)**	

* One way ANOVA hypothesis test

Table 5.17: Secondary data dietary pattern scores ANOVA post-hoc hypothesis tests for the in-between differences for participant education levels

Variable	Variables Compared to	Traditional	Dairy Products	Sea Food	Fast Food
Illiterate (p-value)	**Literate (No school Education)**	0.024	-	<0.001	<0.001
	Primary school	-	0.010	0.16	<0.001
	Intermediate school	-	0.001	<0.001	<0.001
	Secondary or technical school	-	<0.001	<0.001	<0.001
	Bachelor degree	0.006	<0.001	<0.001	<0.001
	Post-graduate degree	0.018	0.002	<0.001	0.001
Literate (with no school Education) (p-value)	**Primary school**	-	-	<0.001	-
	Intermediate school	-	-	<0.001	-
	Secondary or technical school	-	-	<0.001	0.031
	Bachelor degree	-	-	-	-
	Post-graduate degree	-	-	<0.001	-
Primary school (p-value)	**Intermediate school**	-	-	-	0.004
	Secondary or technical school	-	-	0.005	<0.001
	Bachelor degree	-	-	<0.001	-
	Post-graduate degree	-	-	<0.001	-
Intermediate school (p-value)	**Secondary or technical school**	-	-	-	-
	Bachelor degree	-	-	<0.001	-
	Post-graduate degree	-	-	<0.001	-
Secondary or technical school (p-value)	**Bachelor degree**	-	-	<0.001	0.014
	Post-graduate degree	-	-	<0.001	-
Bachelor degree (p-value)	**Post-graduate degree**	-	-	<0.001	-

Only significant p-values are showing

Secondary data dietary patterns association with Smoking status

Figure 5.11 and Table 5.12 explore the relationship between smoking status and the secondary data dietary patterns scores. Smokers had higher mean scores for the Seafood and

Fast Food dietary patterns. Both smokers and non-smokers had very similar mean scores for the Traditional and Dairy Products dietary patterns.

Hypotheses testing revealed that participants who scored high in the Seafood dietary pattern had statistically significant higher odds of being smokers (OR (95%CI=1.166 (1.084-1.254)). This significant association also continue to be significant after adjusting for age and sex (OR (95%CI) =1.181 (1.087-1.283)) (Table 5.12).

Also, participants who scored high in the Fast Food dietary pattern had higher odds of being smokers (OR (95%CI) = 1.141 (1.096-1.187)). This significant association also continue to be present after controlling for age and sex (OR (95%CI) = 1.116 (1.063-1.172)) (Table 5.12).

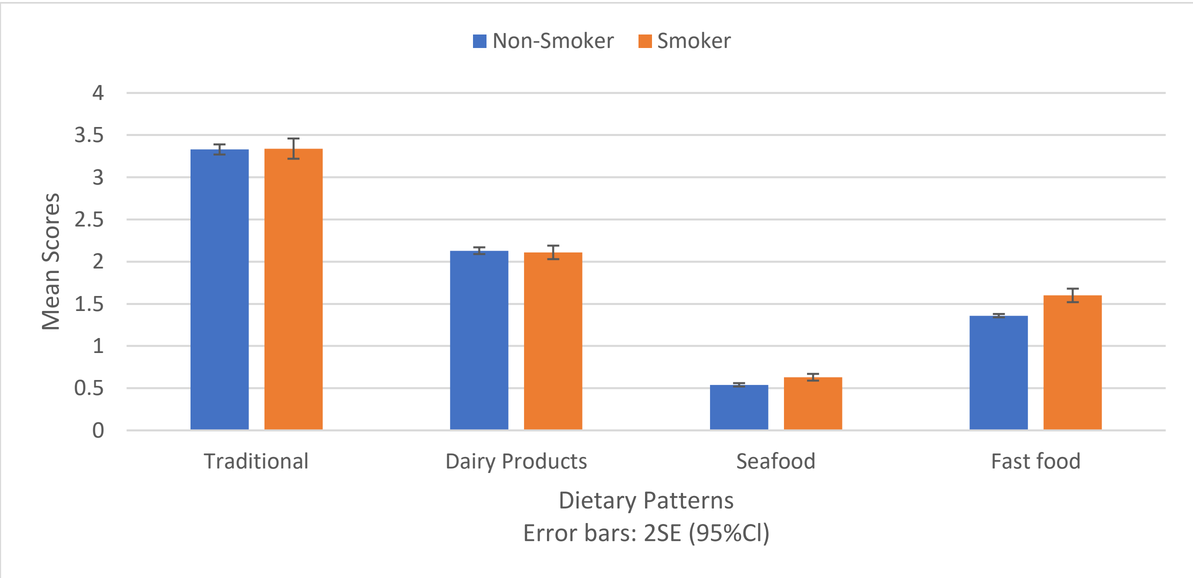

Figure 5.11: Secondary data mean dietary pattern scores stratified by participant smoking status

Table 5.12: Secondary data dietary pattern score mean, standard deviation and odds ratio results stratified by participant smoking status

	Non-Smoker		Smoker		OR of being Smoker (95%Cl)	
	M	**SD**	**M**	**SD**	**Model 1***	**Model 2****

Traditional	3.33	2.38	3.34	2.26	1.001 (0.978-1.026)	0.977 (0.950-1.004)
Dairy Products	2.13	1.65	2.11	1.58	0.991 (0.956-1.026)	1.006 (0.968-1.046)
Seafood	0.54	0.73	0.63	0.73	**1.166 (1.084-1.254)**	**1.181 (1.087-1.283)**
Fast Food	1.36	1.22	1.6	1.35	**1.141 (1.096-1.187)**	**1.116 (1.063-1.172)**

*Unadjusted, *Adjusted to age and sex

Secondary data dietary patterns association with Physical activity

By exploring the distribution of the secondary data, dietary pattern scores by exercising regularly, participants who exercise regularly scored higher for all the dietary patterns (Figure 5.12 and Table 5.13). Hypothesis testing revealed the same finding that participants who had higher scores in all the dietary patterns also had higher odds of exercising regularly (Table 5.13).

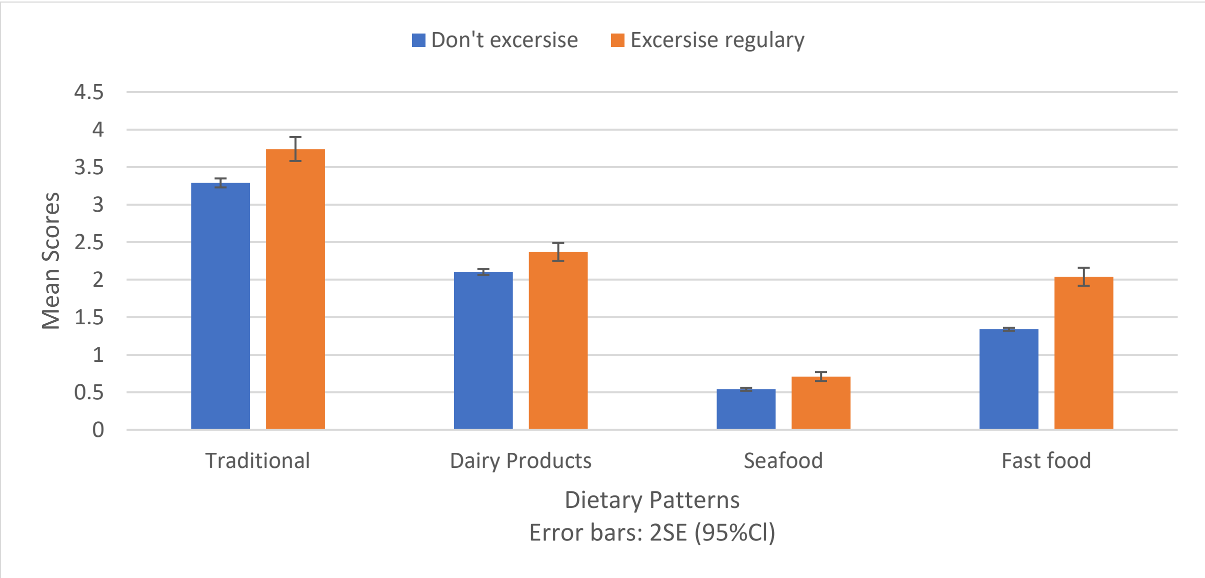

Figure 5.12: Secondary data mean dietary pattern scores stratified by participant physical activity

Table 5.13: Secondary data dietary pattern score mean, standard deviation and odds ratio results stratified by participant physical activity

	Do not exercise		**Exercise regularly**		***OR of exercising regularly (95%Cl)***	
	M	**SD**	**M**	**SD**	**Model 1***	**Model 2****
Traditional	3.29	2.36	3.74	2.34	**1.068 (1.40-1.096)**	**1.070 (1.038-1.102)**
Dairy Products	2.1	1.64	2.37	1.61	**1.081 (1.042-1.122)**	**1.080 (1.035-1.127)**
Seafood	0.54	0.71	0.71	0.84	**1.299 (1.191-1.416)**	**1.386 (1.259-1.526)**
Fast Food	1.34	1.18	2.04	1.62	**1.364 (1.305-1.427)**	**1.157 (1.115-1.237)**

*Unadjusted, **Adjusted to age and sex

Secondary data dietary patterns association with Having a history of chronic cardiovascular disease

Figure 5.13 and Table 5.14 explore the relationship between the dietary pattern scores and the participants having a history of chronic diseases other than T2D. Participants who have a history of chronic diseases other than T2D scored higher for the Seafood dietary patterns. However, hypothesis testing reports no statistically significant differences in dietary pattern scores between participants based on having a diagnosis of chronic diseases other than T2D (Table 5.14).

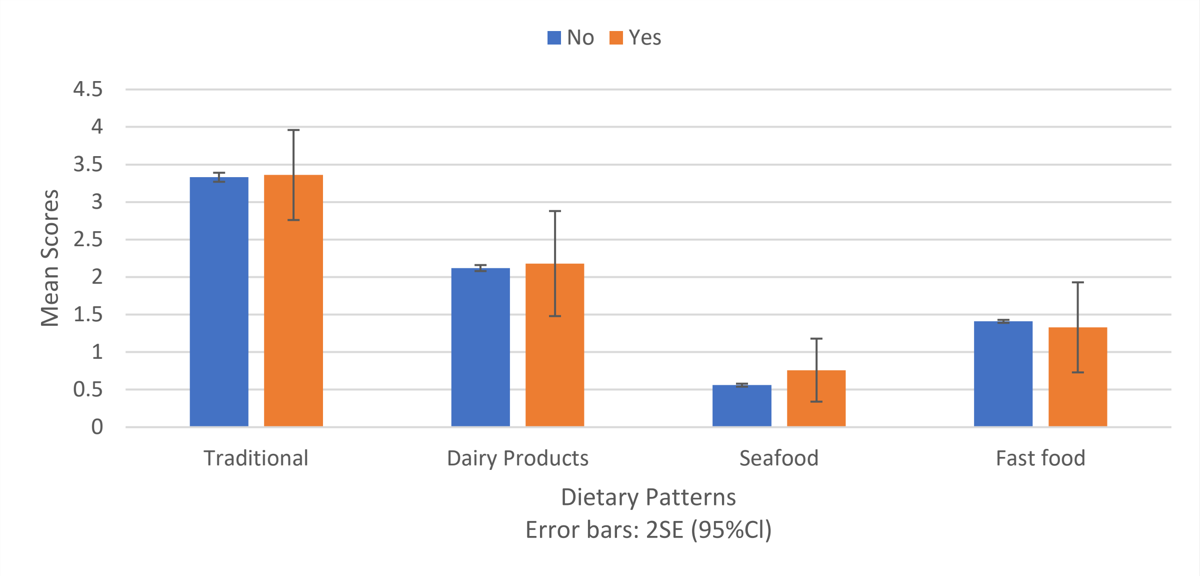

Figure 5.13: Secondary data mean dietary pattern scores stratified by participants having a history of chronic diseases other than T2D

Table 5.14: Secondary data dietary pattern score mean, standard deviation and odds ratio results stratified by participants having a history of chronic disease other than T2D

	History of Cardiovascular Disease					
	No		**Yes**		***OR of having a history of CVD (95%Cl)***	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Model 1***	**Model 2****
Traditional	3.33	2.36	3.36	1.72	1.006 (0.875 - 1.157)	1.012 (0.883 - 1.159)
Dairy Products	2.12	1.64	2.18	2.05	1.020 (0.843 - 1.236)	1.054 (0.886 - 1.253)
Seafood	0.56	0.72	0.76	1.21	1.333 (0.937 - 1.897)	1.373 (0.985 - 1.913)
Fast Food	1.41	1.24	1.33	1.73	0.945 (0.702 - 1.271)	1.157 (0.896 - 1.494)

*Unadjusted, **Adjusted to age and sex

Other descriptive analysis of the SHIS data showing mean frequency of consumption per day stratified by different demographic and health variables

	Age Groups (years)													
	<18		**18-29**		**30-39**		**40-49**		**50-59**		**60-69**		**≥70**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Juice	0.21	0.56	0.3	0.65	0.31	0.6	0.3	0.63	0.28	0.63	0.23	0.56	0.21	0.52
Fruit	0.57	0.78	0.63	0.88	0.73	0.98	0.77	1.05	0.79	1.1	0.72	1.01	0.7	0.95
Vegetables	0.94	1.1	1	1.13	1.15	1.25	1.15	1.26	1.19	1.28	1.04	1.15	1	1.29
Dark Fish	0.16	0.32	0.17	0.35	0.19	0.4	0.16	0.38	0.11	0.22	0.13	0.4	0.07	0.25
Other Fish	0.17	0.4	0.16	0.3	0.19	0.37	0.18	0.35	0.17	0.33	0.14	0.27	0.12	0.37
Red Meat	0.51	0.59	0.54	0.64	0.58	0.69	0.57	0.69	0.58	0.77	0.59	0.77	0.61	0.78
Poultry	1.34	1.34	1.21	1.22	1.19	1.17	1.13	1.14	1.14	1.29	1.04	1.19	0.95	1.1
Shrimp	0.02	0.09	0.04	0.12	0.05	0.23	0.03	0.16	0.03	0.16	0.03	0.26	0.01	0.08
Processed Meat	0.12	0.31	0.13	0.41	0.07	0.21	0.06	0.25	0.03	0.12	0.02	0.1	0.02	0.19
Processed Food	0.31	0.53	0.36	0.72	0.26	0.51	0.19	0.37	0.17	0.43	0.12	0.29	0.08	0.25
Eggs	0.56	0.78	0.55	0.67	0.59	0.74	0.53	0.64	0.51	0.74	0.4	0.58	0.34	0.39
Nuts	0.38	0.65	0.33	0.61	0.27	0.47	0.27	0.55	0.24	0.59	0.14	0.37	0.09	0.26
Milk	0.88	1.17	0.84	1.19	0.87	1.23	0.84	1.18	0.91	1.21	0.9	1.1	1.14	1.32
Labneh	0.21	0.52	0.21	0.51	0.22	0.52	0.2	0.45	0.19	0.41	0.14	0.3	0.13	0.5
Laban	0.58	0.86	0.6	0.91	0.66	0.95	0.67	0.99	0.73	1	0.69	0.85	0.81	1.1

Yogurt	0.44	0.8	0.41	0.68	0.46	0.73	0.43	0.76	0.45	0.79	0.48	0.9	0.47	0.9
Cheese	0.96	1.15	0.9	1.07	0.89	1.09	0.79	0.98	0.73	0.97	0.58	0.65	0.51	0.82
Carbonated Drinks	1.32	1.39	1.09	1.33	0.74	1.08	0.5	0.82	0.35	0.72	0.19	0.37	0.24	0.6

	Sex			
	Female		**Male**	
	M	**SD**	**M**	**SD**
Juice	0.27	0.56	0.3	0.67
Fruit	0.66	0.91	0.75	1.02
Vegetables	1.06	1.2	1.11	1.23
Dark Fish	0.16	0.36	0.16	0.35
Other Fish	0.17	0.33	0.18	0.35
Red Meat	0.46	0.59	0.67	0.76
Poultry	1.09	1.17	1.24	1.23
Shrimp	0.03	0.11	0.04	0.22
Processed Meat	0.08	0.28	0.07	0.29
Processed Food	0.23	0.46	0.27	0.61
Eggs	0.5	0.65	0.56	0.72
Nuts	0.27	0.54	0.27	0.55
Milk	0.89	1.21	0.87	1.2
Labneh	0.21	0.47	0.19	0.49
Laban	0.63	0.92	0.69	0.99
Yogurt	0.46	0.79	0.42	0.72
Cheese	0.87	1.09	0.78	0.96

Carbonated Drinks	0.62	1.02		0.85	1.19

	Diagnosis Group					
	Non-diabetic		**Diagnosed T2D**		**Undiagnosed T2D**	
	M	**SD**	**M**	**SD**	**M**	**SD**
Juice	0.29	0.62	0.26	0.64	0.25	0.43
Fruit	0.68	0.94	0.79	1.08	0.86	1.09
Vegetables	1.08	1.21	1.13	1.2	1.11	1.31
Dark Fish	0.16	0.35	0.11	0.26	0.17	0.36
Other Fish	0.18	0.35	0.14	0.26	0.12	0.21
Red Meat	0.55	0.67	0.64	0.76	0.66	0.73
Poultry	1.16	1.2	1.1	1.2	1.34	1.33
Shrimp	0.04	0.16	0.04	0.27	0.02	0.11
Processed Meat	0.09	0.3	0.03	0.12	0.07	0.23
Processed Food	0.27	0.57	0.12	0.27	0.19	0.37
Eggs	0.54	0.69	0.49	0.79	0.52	0.52
Nuts	0.28	0.53	0.2	0.54	0.31	0.63
Milk	0.87	1.2	0.93	1.27	0.98	1.27
Labneh	0.21	0.49	0.18	0.33	0.16	0.52
Laban	0.64	0.93	0.77	1.03	0.69	1.06
Yoghurt	0.44	0.74	0.47	0.83	0.4	0.66
Cheese	0.85	1.05	0.71	1.01	0.66	0.69
Carbonated Drinks	0.8	1.15	0.29	0.67	0.58	0.85

	HbA1c Results		
	Non-DM **(<6.0%)**	**pre-DM** **(6.0-6.5%)**	**DM** **(>6.5%)**

	M	SD	M	SD	M	SD
Juice	0.29	0.63	0.24	0.57	0.23	0.48
Fruit	0.7	0.98	0.69	0.97	0.73	0.93
Vegetables	1.08	1.2	1.09	1.13	1.08	1.17
Dark Fish	0.16	0.32	0.18	0.43	0.17	0.41
Other Fish	0.17	0.35	0.2	0.41	0.18	0.41
Red Meat	0.55	0.66	0.57	0.72	0.63	0.79
Poultry	1.15	1.18	1.19	1.11	1.23	1.18
Shrimp	0.04	0.2	0.04	0.29	0.03	0.11
Processed Meat	0.08	0.32	0.06	0.19	0.07	0.29
Processed Food	0.25	0.58	0.25	0.48	0.25	0.54
Eggs	0.53	0.66	0.51	0.55	0.52	0.79
Nuts	0.27	0.52	0.27	0.56	0.28	0.53
Milk	0.88	1.2	0.84	1.13	0.88	1.12
Labneh	0.2	0.47	0.18	0.35	0.2	0.55
Laban	0.67	0.97	0.58	0.78	0.62	0.91
Yogurt	0.43	0.7	0.44	0.75	0.42	0.64
Cheese	0.82	1.01	0.83	0.96	0.84	0.98
Carbonated Drinks	0.75	1.14	0.75	1.14	0.65	0.92

	HbA1c Results excluding T2D					
	Non-DM (<6.0%)		**pre-DM (6.0-6.5%)**		**DM (>6.5%)**	
	M	**SD**	**M**	**SD**	**M**	**SD**
Juice	0.3	0.62	0.21	0.4	0.24	0.49
Fruit	0.7	1	0.66	0.91	0.72	0.88

Vegetables	1.07	1.2	1.08	1.11	1.1	1.17
Dark Fish	0.16	0.33	0.18	0.44	0.17	0.43
Other Fish	0.17	0.34	0.21	0.43	0.19	0.43
Red Meat	0.55	0.66	0.57	0.66	0.62	0.79
Poultry	1.16	1.18	1.17	1.06	1.26	1.21
Shrimp	0.04	0.16	0.04	0.3	0.03	0.12
Processed Meat	0.09	0.33	0.07	0.2	0.08	0.31
Processed Food	0.26	0.6	0.26	0.47	0.27	0.57
Eggs	0.53	0.65	0.52	0.55	0.55	0.82
Nuts	0.28	0.52	0.28	0.58	0.28	0.47
Milk	0.88	1.2	0.81	1.05	0.87	1.14
Labneh	0.2	0.49	0.18	0.34	0.21	0.58
Laban	0.65	0.96	0.58	0.8	0.62	0.88
Yogurt	0.43	0.71	0.42	0.67	0.44	0.66
Cheese	0.84	1.02	0.84	0.98	0.88	1.01
Carbonated Drinks	0.81	1.18	0.82	1.18	0.7	0.95

	BMI groups							
	Underweight (<18.5)		**Normal (18.5-24.9)**		**Overweight (25-29.9)**		**Obese (≥30)**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Juice	0.24	0.6	0.28	0.62	0.29	0.59	0.28	0.63
Fruit	0.54	0.8	0.65	0.86	0.73	1.01	0.74	1.03
Vegetables	0.98	1.16	1.04	1.15	1.07	1.19	1.14	1.27
Dark Fish	0.16	0.32	0.16	0.33	0.15	0.34	0.15	0.34
Other Fish	0.2	0.43	0.16	0.32	0.18	0.34	0.16	0.32

Red Meat	0.45	0.53	0.54	0.67	0.59	0.7	0.58	0.72
Poultry	1.13	1.13	1.17	1.25	1.16	1.2	1.18	1.19
Shrimp	0.03	0.13	0.03	0.16	0.04	0.18	0.03	0.15
Processed Meat	0.11	0.43	0.07	0.23	0.09	0.32	0.07	0.27
Processed Food	0.34	0.7	0.26	0.53	0.23	0.52	0.24	0.52
Eggs	0.5	0.67	0.52	0.69	0.55	0.65	0.53	0.7
Nuts	0.31	0.63	0.27	0.54	0.25	0.48	0.28	0.6
Milk	0.9	1.23	0.9	1.24	0.88	1.17	0.84	1.19
Labneh	0.21	0.46	0.2	0.52	0.19	0.43	0.2	0.47
Laban	0.65	1.01	0.63	0.96	0.66	0.93	0.69	0.99
Yogurt	0.4	0.73	0.42	0.77	0.42	0.71	0.46	0.78
Cheese	0.91	1.13	0.86	1.07	0.8	1	0.8	0.98
Carbonated Drinks	1.13	1.36	0.87	1.22	0.64	0.99	0.65	1.07

	Income estimation (SAR)									
	< 5000		**5000 - 10,000**		**10,000 - 15,000**		**15,000 - 20,000**		**> 20,000**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Juice	0.21	0.52	0.28	0.56	0.34	0.66	0.42	0.85	0.6	1.1
Fruit	0.57	0.82	0.7	0.91	0.83	1.11	0.91	1.21	1.07	1.45
Vegetables	0.98	1.12	1.08	1.11	1.2	1.39	1.2	1.34	1.69	1.59
Dark Fish	0.13	0.35	0.16	0.33	0.19	0.4	0.2	0.48	0.2	0.48
Other Fish	0.15	0.32	0.18	0.37	0.21	0.43	0.2	0.32	0.21	0.39

Red Meat	0.49	0.68	0.57	0.72	0.59	0.64	0.65	0.79	0.73	0.86
Poultry	1.12	1.18	1.16	1.07	1.1	1.06	1.11	1.13	2	2.27
Shrimp	0.02	0.11	0.03	0.15	0.05	0.19	0.07	0.3	0.09	0.41
Processed Meat	0.06	0.29	0.09	0.3	0.07	0.21	0.08	0.25	0.06	0.18
Processed Food	0.24	0.56	0.27	0.57	0.25	0.47	0.26	0.62	0.27	0.57
Eggs	0.48	0.66	0.54	0.66	0.59	0.74	0.63	0.81	0.58	0.92
Nuts	0.21	0.47	0.28	0.57	0.31	0.55	0.37	0.69	0.34	0.75
Milk	0.86	1.15	0.81	1.11	0.83	1.19	0.82	1.29	1.4	1.84
Labneh	0.16	0.47	0.22	0.46	0.25	0.62	0.26	0.51	0.23	0.53
Laban	0.67	0.98	0.65	0.9	0.72	1.07	0.61	0.9	0.85	1.27
Yogurt	0.41	0.76	0.47	0.78	0.45	0.73	0.47	0.84	0.46	0.83
Cheese	0.78	1.08	0.82	0.98	0.9	1.06	0.91	1.12	1.12	1.36
Carbonated Drinks	0.77	1.23	0.75	1.1	0.7	0.99	0.65	0.9	0.65	1.05

	Education group													
	Illiterate		**Literate**		**Primary school**		**Intermediate school**		**Secondary or technical school**		**Bachelor degree**		**Post-graduate degree**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**

Juice	0.17	0.43	0.3	0.57	0.21	0.56	0.25	0.58	0.29	0.59	0.38	0.74	0.6	0.91
Fruit	0.61	0.87	0.82	0.97	0.62	0.85	0.65	0.89	0.65	0.89	0.84	1.14	1.24	1.66
Vegetables	0.99	1.15	1.01	1.01	1.02	1.18	1.05	1.14	1.07	1.21	1.21	1.32	1.6	1.62
Dark Fish	0.1	0.31	0.2	0.42	0.14	0.3	0.16	0.36	0.16	0.36	0.19	0.34	0.31	0.71
Other Fish	0.13	0.32	0.17	0.29	0.18	0.4	0.18	0.37	0.17	0.34	0.18	0.31	0.24	0.35
Red Meat	0.55	0.75	0.61	0.68	0.54	0.64	0.55	0.63	0.58	0.73	0.56	0.65	0.64	0.87
Poultry	1.1	1.22	1.25	1.27	1.16	1.19	1.21	1.15	1.18	1.24	1.12	1.17	1.11	1.17
Shrimp	0.01	0.04	0.02	0.09	0.02	0.1	0.03	0.15	0.04	0.19	0.06	0.21	0.15	0.48
Processed Meat	0.03	0.24	0.14	0.35	0.05	0.18	0.08	0.28	0.09	0.3	0.09	0.31	0.07	0.16
Processed Food	0.13	0.33	0.21	0.41	0.18	0.39	0.26	0.54	0.31	0.65	0.28	0.57	0.28	0.45
Eggs	0.38	0.52	0.52	0.62	0.46	0.59	0.55	0.69	0.56	0.69	0.59	0.76	0.82	1.06
Nuts	0.15	0.51	0.39	0.69	0.24	0.51	0.27	0.5	0.29	0.57	0.29	0.5	0.41	0.75

Milk	1.04	1.24	0.99	1.1	0.91	1.26	0.81	1.05	0.83	1.2	0.85	1.27	1.08	1.63
Labneh	0.12	0.36	0.13	0.28	0.17	0.42	0.19	0.43	0.22	0.54	0.25	0.55	0.36	0.7
Laban	0.72	1	0.67	0.98	0.63	0.9	0.65	0.91	0.63	0.95	0.67	1	0.7	0.88
Yogurt	0.42	0.79	0.44	0.73	0.46	0.87	0.4	0.64	0.44	0.75	0.47	0.77	0.58	0.99
Cheese	0.61	0.88	0.69	0.87	0.79	1	0.83	0.98	0.87	1.04	0.93	1.13	1.2	1.43
Carbonated Drinks	0.28	0.64	0.52	0.78	0.73	1.15	0.91	1.22	0.9	1.25	0.73	1.06	0.66	1.02

	Non-Smoker		**Smoker**	
	M	**SD**	**M**	**SD**
Juice	0.28	0.6	0.31	0.68
Fruit	0.7	0.98	0.72	0.95
Vegetables	1.08	1.22	1.12	1.19
Dark Fish	0.16	0.34	0.18	0.42
Other Fish	0.17	0.34	0.19	0.36
Red Meat	0.55	0.67	0.64	0.79
Poultry	1.16	1.21	1.19	1.16
Shrimp	0.03	0.16	0.06	0.23
Processed Meat	0.08	0.27	0.09	0.34
Processed Food	0.24	0.52	0.3	0.62

Eggs	0.52	0.66	0.6	0.78
Nuts	0.26	0.54	0.31	0.57
Milk	0.91	1.22	0.75	1.15
Labneh	0.2	0.47	0.22	0.53
Laban	0.66	0.96	0.66	0.95
Yogurt	0.44	0.77	0.45	0.71
Cheese	0.83	1.04	0.81	0.98
Carbonated Drinks	0.69	1.08	0.92	1.25

	Exercise			
	Don't exercise		**Exercise regularly**	
	M	**SD**	**M**	**SD**
Juice	0.28	0.61	0.35	0.67
Fruit	0.69	0.97	0.8	0.99
Vegetables	1.08	1.21	1.15	1.27
Dark Fish	0.16	0.35	0.21	0.4
Other Fish	0.17	0.34	0.19	0.38
Red Meat	0.55	0.68	0.69	0.79
Poultry	1.15	1.2	1.33	1.24
Shrimp	0.04	0.18	0.05	0.14
Processed Meat	0.08	0.28	0.11	0.35
Processed Food	0.24	0.51	0.38	0.76
Eggs	0.53	0.69	0.57	0.6
Nuts	0.26	0.53	0.38	0.64
Milk	0.88	1.22	0.83	1.11

Labneh	0.2	0.48	0.23	0.46
Laban	0.66	0.96	0.68	0.95
Yogurt	0.44	0.75	0.49	0.8
Cheese	0.82	1.03	0.91	1.06
Carbonated Drinks	0.68	1.06	1.23	1.45

	Cardiovascular disease			
	No		**Yes**	
	M	**SD**	**M**	**SD**
Juice	0.28	0.61	0.39	0.59
Fruit	0.7	0.97	0.66	0.83
Vegetables	1.08	1.21	1.09	0.95
Dark Fish	0.16	0.36	0.05	0.08
Other Fish	0.17	0.34	0.12	0.35
Red Meat	0.56	0.69	0.58	0.63
Poultry	1.16	1.2	0.92	0.79
Shrimp	0.04	0.17	0.04	0.11
Processed Meat	0.08	0.28	0.25	1.15
Processed Food	0.25	0.54	0.27	0.65
Eggs	0.53	0.69	0.4	0.45
Nuts	0.27	0.54	0.44	0.74
Milk	0.88	1.21	0.8	0.79
Labneh	0.2	0.48	0.29	0.65
Laban	0.66	0.96	0.9	1.25
Yogurt	0.44	0.76	0.55	0.64
Cheese	0.83	1.03	0.67	0.9

Carbonated Drinks	0.73	1.12	0.54	1.05

	Having a history of chronic disease other than T2D			
	No		**Yes**	
	M	**SD**	**M**	**SD**
Red Meat	0.55	0.67	0.42	0.48
Chicken	0.8	0.8	0.57	0.6
Fried Chicken and Fish	0.2	0.34	0.2	0.38
Seafood	0.3	0.4	0.2	0.5
Processed Meat	0.14	0.26	0.07	0.22
Rice and Macaroni	0.95	1.07	0.96	0.99
White Bread	0.46	0.81	0.27	0.55
Brown Bread	0.48	0.7	0.68	0.9
Baked Items	0.37	0.51	0.43	1.19
Non-fried Potato	0.1	0.2	0.18	0.38
Fried Potato	0.13	0.19	0.12	0.24
Sugary Breakfast	0.19	0.45	0.13	0.38
Sandwiches	0.49	0.54	0.41	0.66
Full fat dairy items	1.65	1.54	1.31	1.26
Low and fat-free dairy items	1.26	2.08	1.13	1.44
Margarine and Butter	0.16	0.26	0.21	0.63
Eggs	0.28	0.34	0.26	0.67
Confectionery and Other Sweets	0.83	1.16	0.65	1.09
Crisps	0.17	0.55	0.08	0.22
Nuts	0.15	0.25	0.12	0.22
Dried Fruits and Pickles	0.27	0.37	0.32	0.59

Soup	0.16	0.54	0.09	0.21
Sugar (Added to coffee or tea)	0.51	0.89	0.48	1.28
Sauces such as ketchup and mayo	0.27	0.48	0.42	1.15
Tea and Coffee	3.36	3.29	2.94	2.84
Cold beverages	0.77	1	0.77	2.22
Fruits	3.05	2.46	3.03	4.36
Vegetables	4.29	3.9	4.72	6.59

	Family History of DM			
	No		**Yes**	
	M	**SD**	**M**	**SD**
Juice	0.21	0.41	0.27	0.7
Fruit	0.89	1.29	0.81	1.09
Vegetables	1.13	1.29	1.14	1.25
Dark Fish	0.11	0.23	0.15	0.43
Other Fish	0.15	0.28	0.16	0.35
Red Meat	0.61	0.88	0.61	0.81
Poultry	1.2	1.38	1.04	1.09
Shrimp	0.02	0.09	0.04	0.34
Processed Meat	0.03	0.11	0.04	0.2
Processed Food	0.13	0.28	0.17	0.39
Eggs	0.49	0.8	0.48	0.71
Nuts	0.2	0.67	0.24	0.62
Milk	0.99	1.37	0.83	1.19
Labneh	0.19	0.42	0.16	0.31
Laban	0.81	1.15	0.76	1.08
Yogurt	0.56	1.1	0.47	0.84

Cheese	0.73	1.17	0.74	0.99
Carbonated Drinks	0.3	0.85	0.37	0.77

Appendix 5: The primary data additional analysis

Primary data sample distribution by diagnosis groups

Figure 6.2 shows the proportional distribution of each of the three diagnosis groups of non-diabetics, undiagnosed diabetics and diagnosed type 2 diabetics stratified by age group. Large proportions of the young age groups are non-diabetics while large proportions of the old age groups are diagnosed with type 2 diabetes. Undiagnosed diabetes is more common in the youngest age group of 18-29 years followed by 30-39 years in comparison with other age groups for the study sample. Within the primary data also, more of the undiagnosed diabetics are females while more of the non-diabetics are males (Figure 6.3).

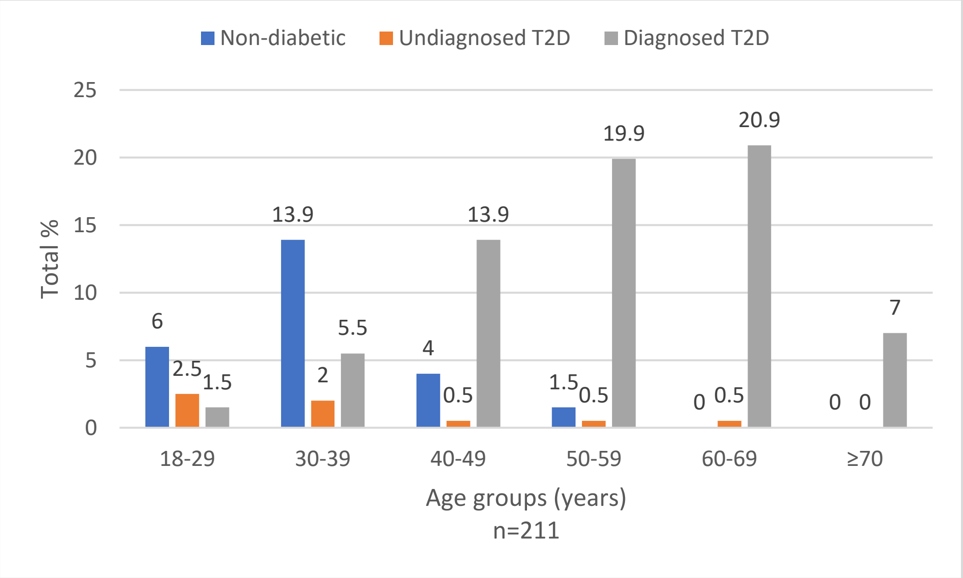

Figure 6.2: Primary data distribution for diagnosis groups by age group

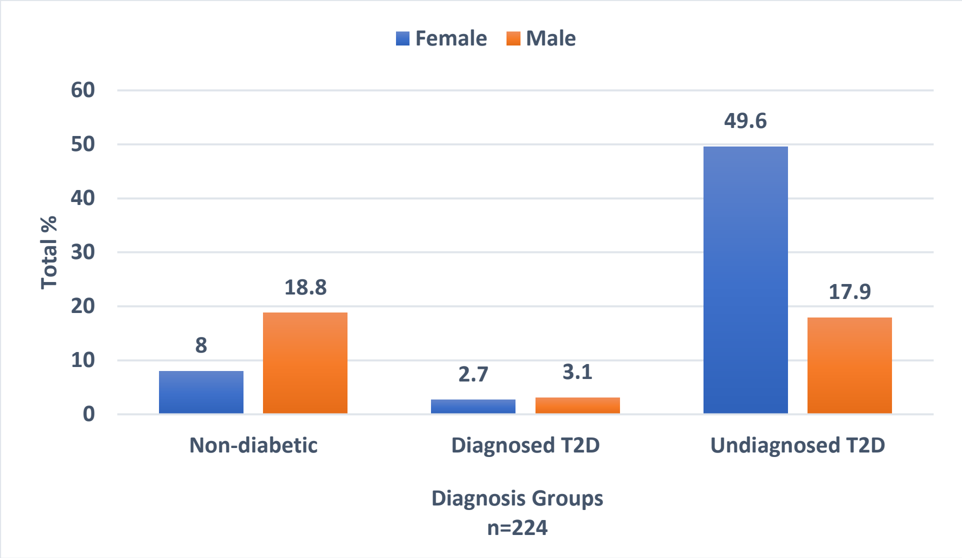

Figure 6.3: Primary data distribution for diagnosis groups by sex

Primary data sample distribution by HbA1c levels

HbA1c distribution by age group and sex shows that HbA1c levels increase with age within the primary data sample (Figure 6.4). This can be explained by those diagnosed with T2D who dominate the older age groups within the primary data sample. HbA1c is also higher in females compared to males (Figure 6.5) following the same pattern seen for diagnosed and undiagnosed T2D.

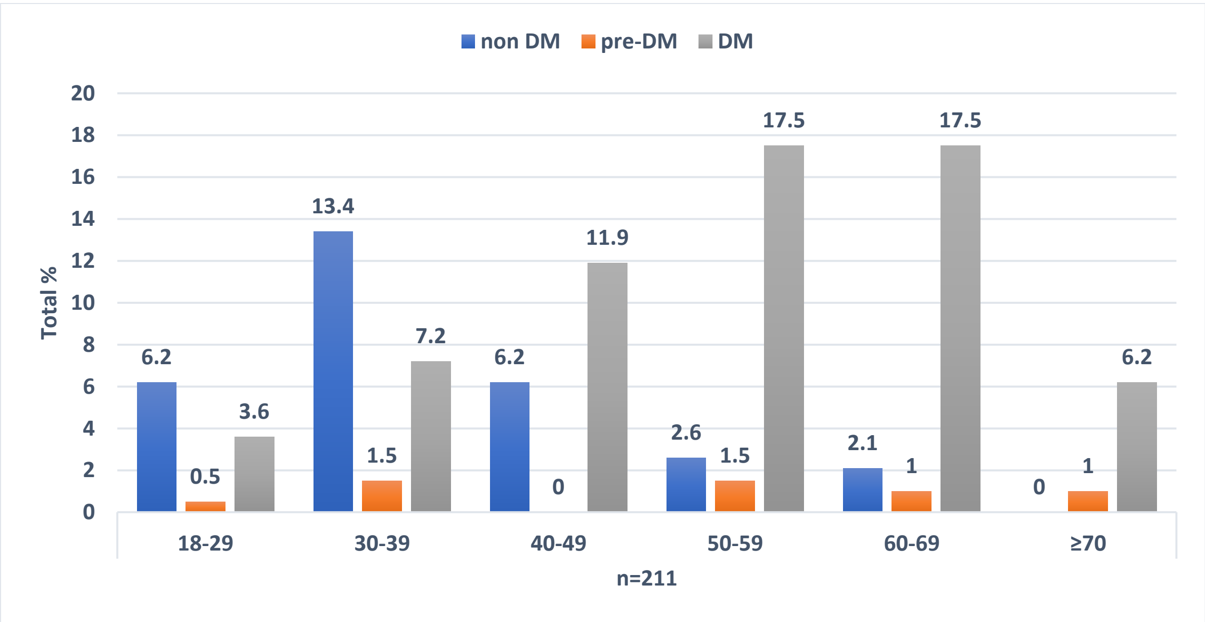

Figure 6.4: Primary data distribution for HbA1c diagnosis groups by age group

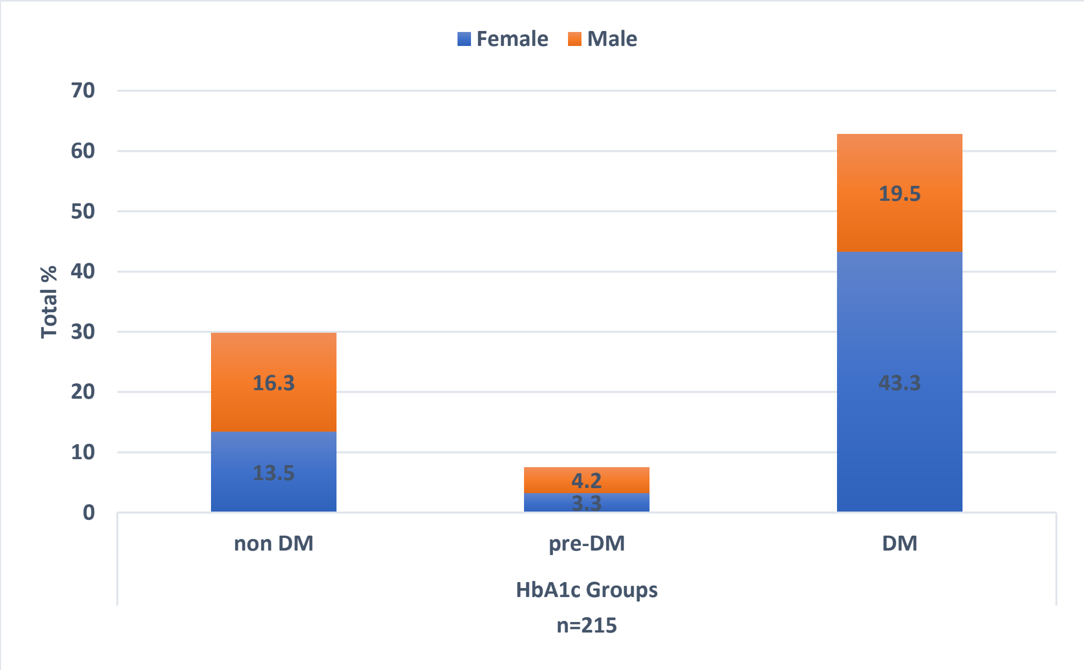

Figure 6.5: Primary data distribution for HbA1c diagnosis groups by sex

Primary data sample distribution by HbA1c levels (excluding diagnosed T2D)

After excluding those who already have a T2D diagnosis (who might be taking glucose controlling medications or have poor control over their blood sugar), the distribution of HbA1c levels by age group for the primary data sample can be seen in Figure 6.6. There is a general decrease in HbA1c levels compared to the levels seen before excluding those with a type 2 diabetes diagnosis. This suggests that overall, those diagnosed with T2D do not have well-controlled blood glucose.

Sex distribution for the primary data HbA1c groups after excluding those diagnosed with T2D can be seen in Figure 6.7.

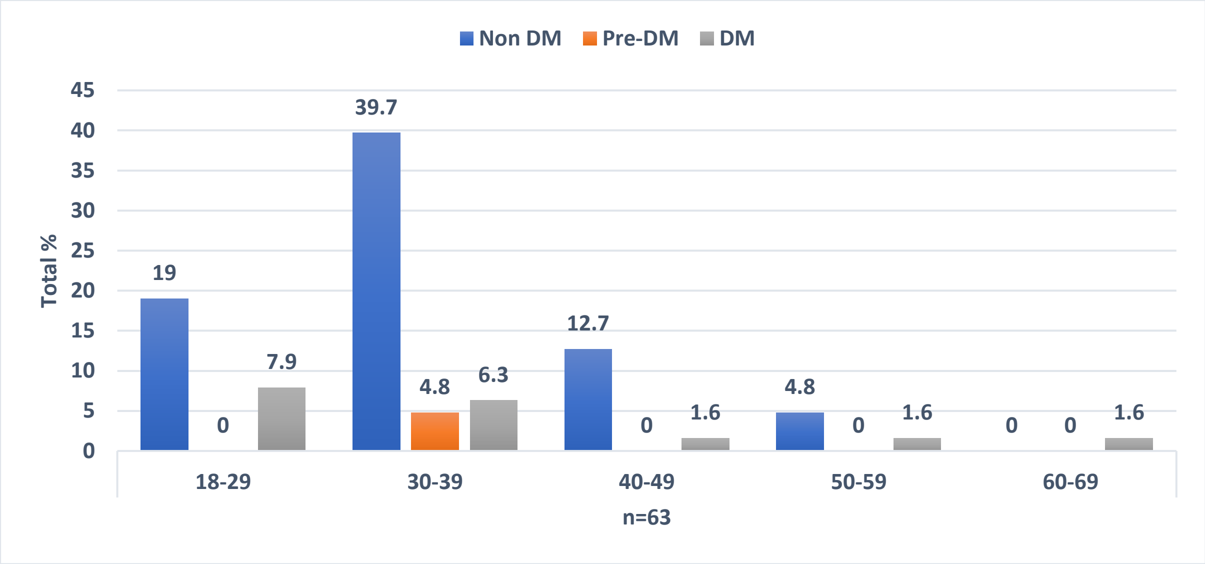

Figure 6.6: Primary data distribution for HbA1c diagnosis groups excluding those diagnosed with T2D by age group

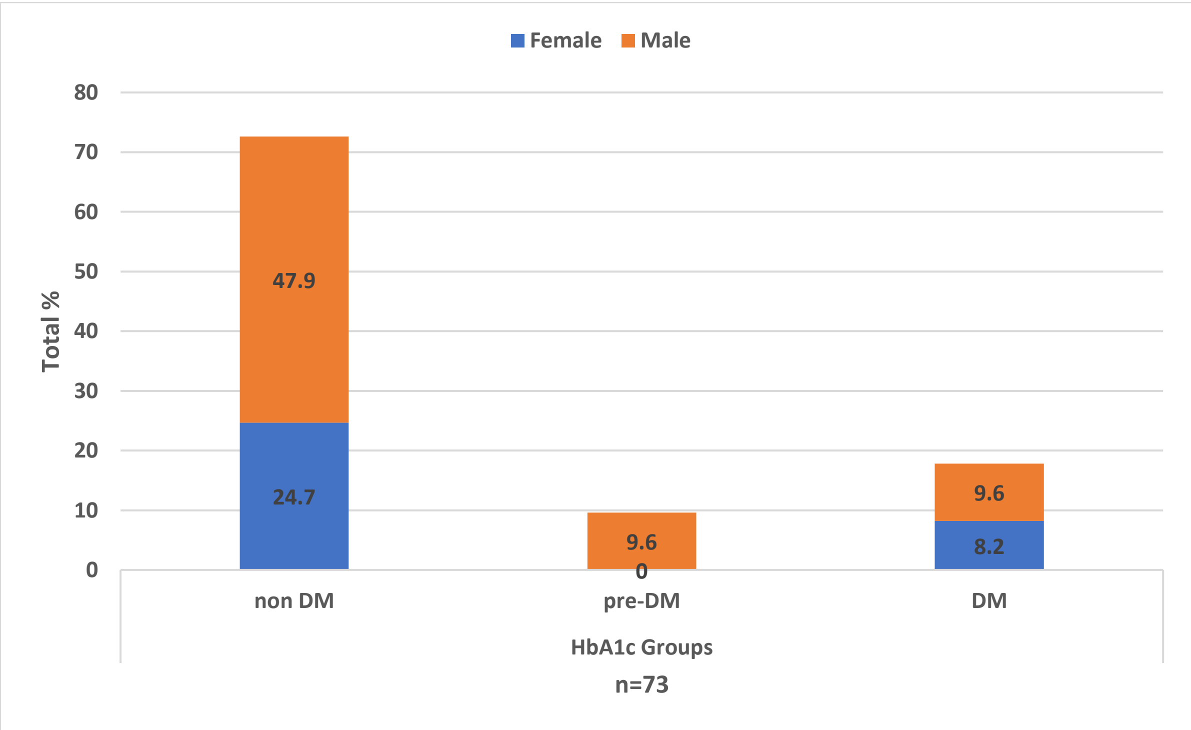

Figure 6.7: Primary data distribution for HbA1c diagnosis excluding T2D groups by sex

Primary data sample distribution by body Mass Index levels

BMI distribution within the primary data by age group and sex shows that BMI levels are in the overweight and obese categories for most of the sample except for the youngest age group (18-29 years) (Figure 6.8). Regarding sex, the proportions for both females and males appear similar except for the obese category of BMI level where there is a higher proportion for females compared to males (Figure 6.9).

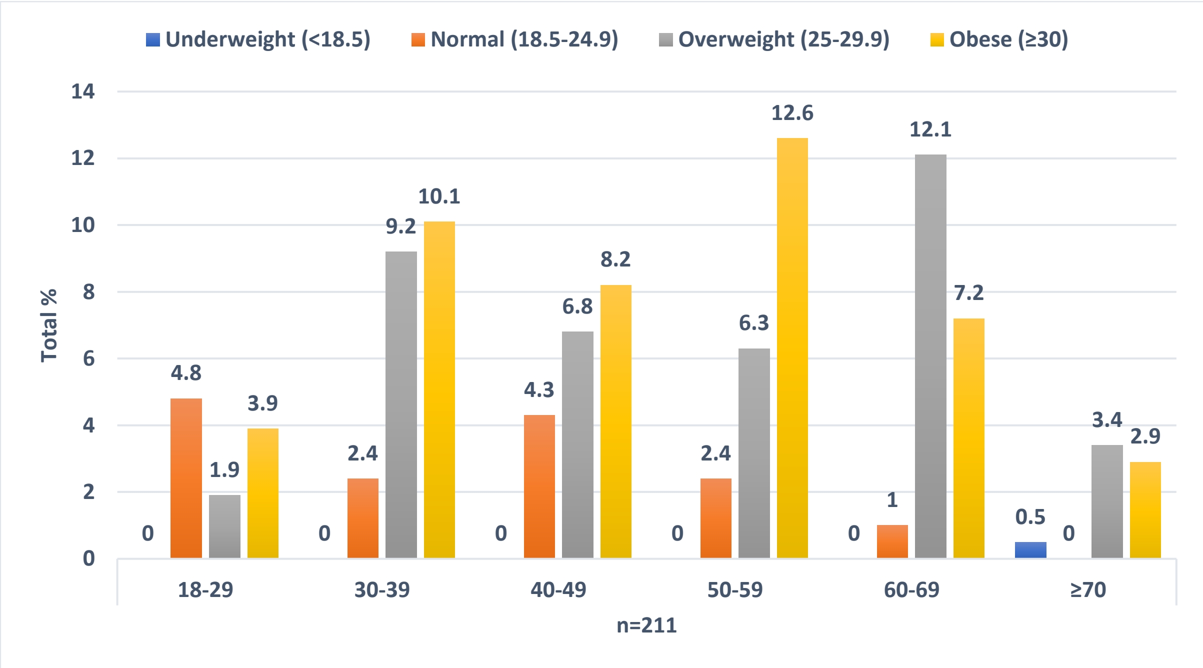

Figure 6.8: Primary data distribution for BMI by age group

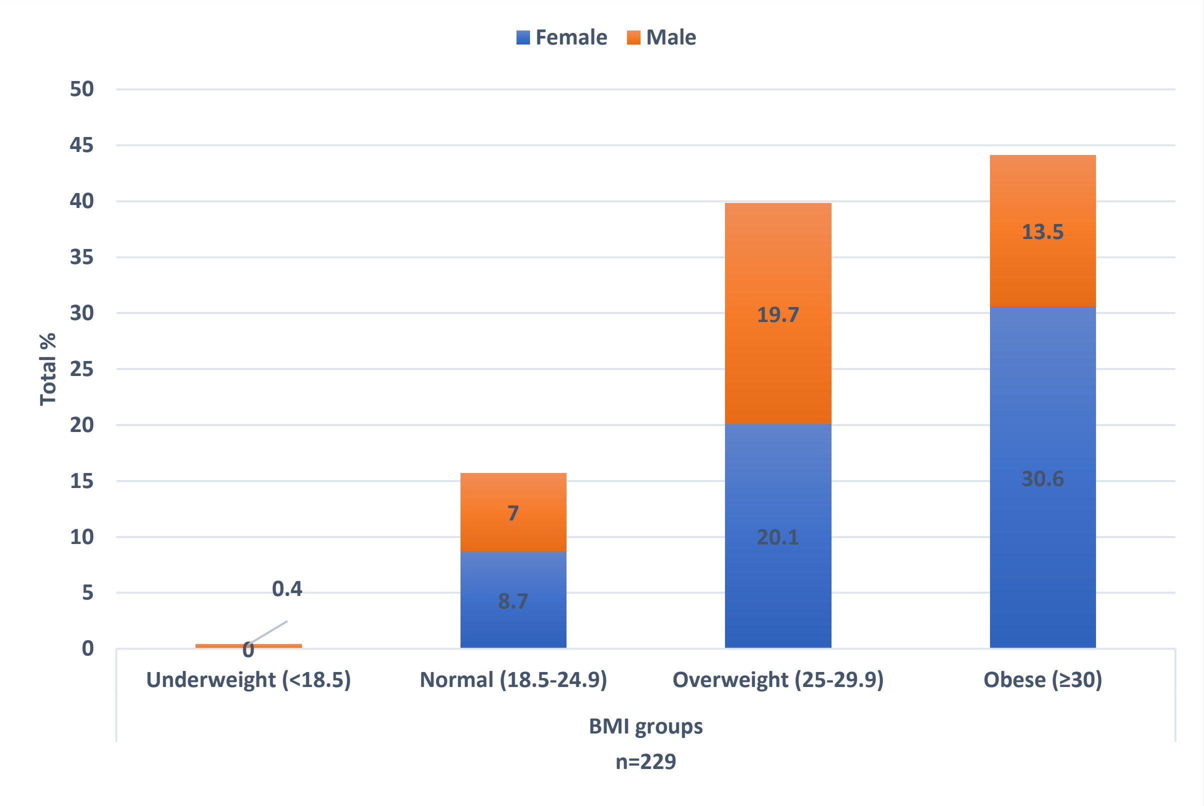

Figure 6.9: Primary data distribution for BMI by sex

Primary data sample distribution by household monthly income estimation

Figures 6.10 and 6.11 show the distribution for the estimated household monthly incomes (as a measure for socioeconomic status) among the age groups. The younger age groups have higher proportions of high-income levels compared to the older age groups. This pattern is similar to the one seen in the secondary data distribution in Figure 5.10. Distribution for income estimates by sex shows that males have higher income levels in general within the primary data sample which is also similar to the secondary data sample distribution seen in Figure 5.11.

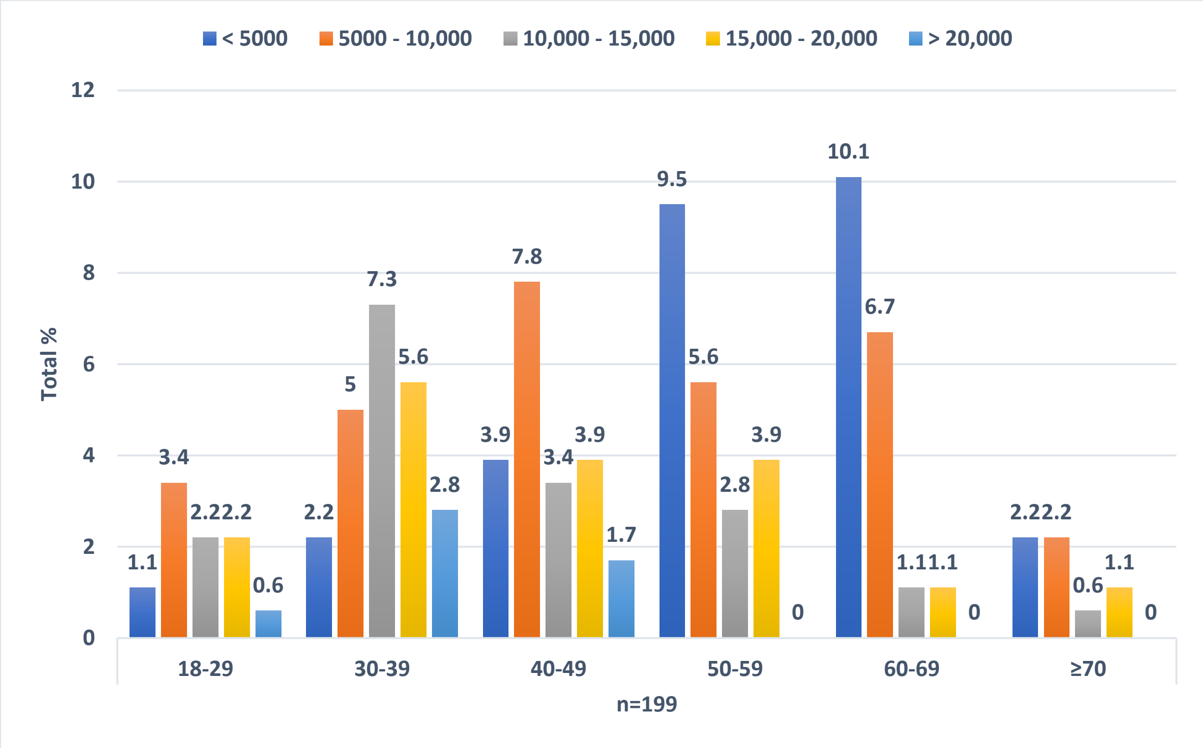

Figure 6.10: Primary data distribution for estimated household monthly income by age group

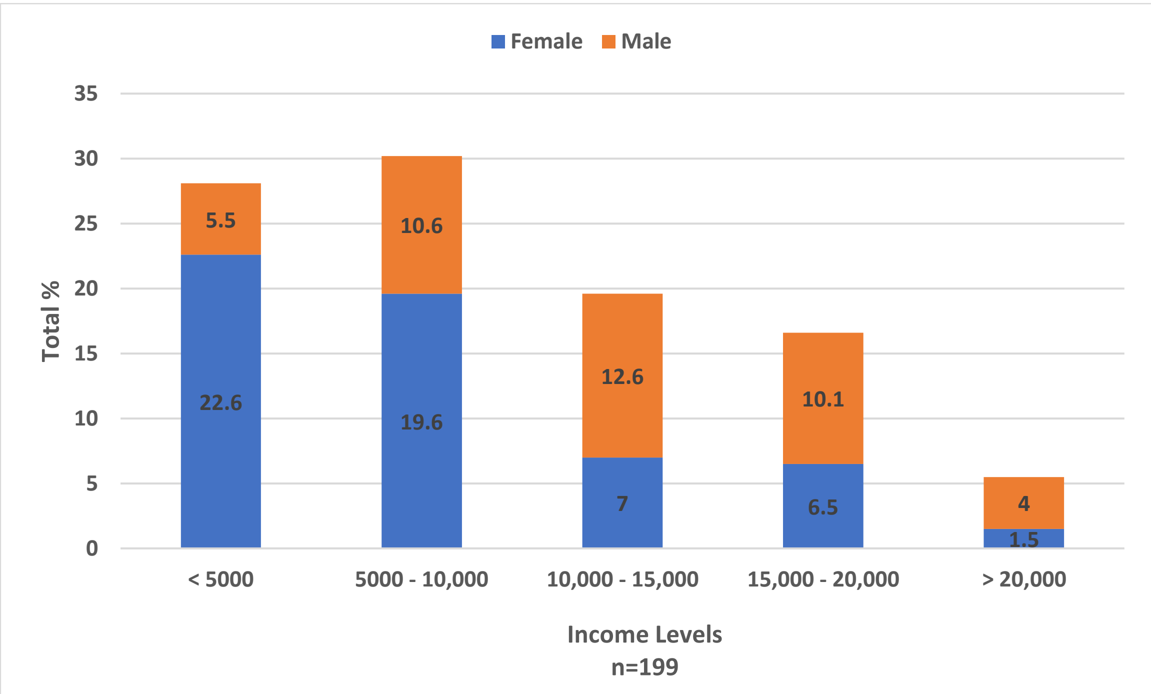

Figure 6.11: Primary data distribution for estimated household monthly income by sex

Primary data sample distribution by Education levels

Distribution in the secondary data sample for education level while also being stratified by age group and sex can be seen in Figure 6.12 and Figure 6.13. In general, the education levels are higher in the younger generations for the primary data sample compared to the older ones, which is similar to the pattern seen in the secondary data sample Figure 5.12. By comparing both sexes, males have higher numbers with a higher level of education compared to females, which is also similar to the pattern seen in Figure 5.13 of the secondary data sample.

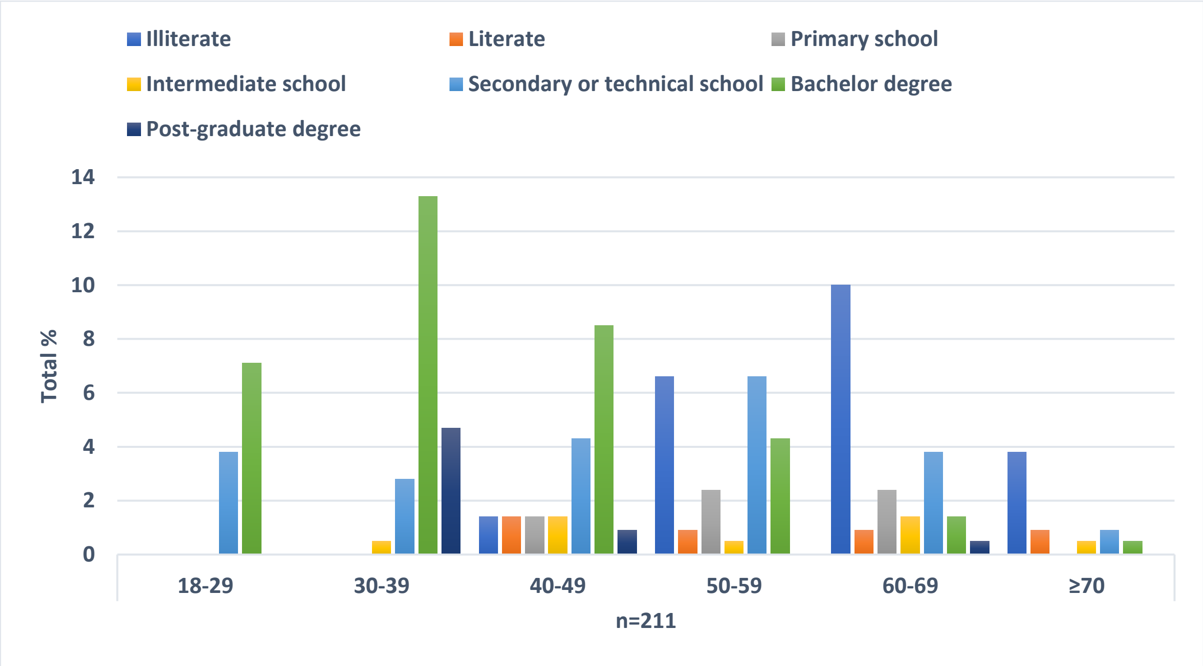

Figure 6.12: Primary data distribution for education level by age group

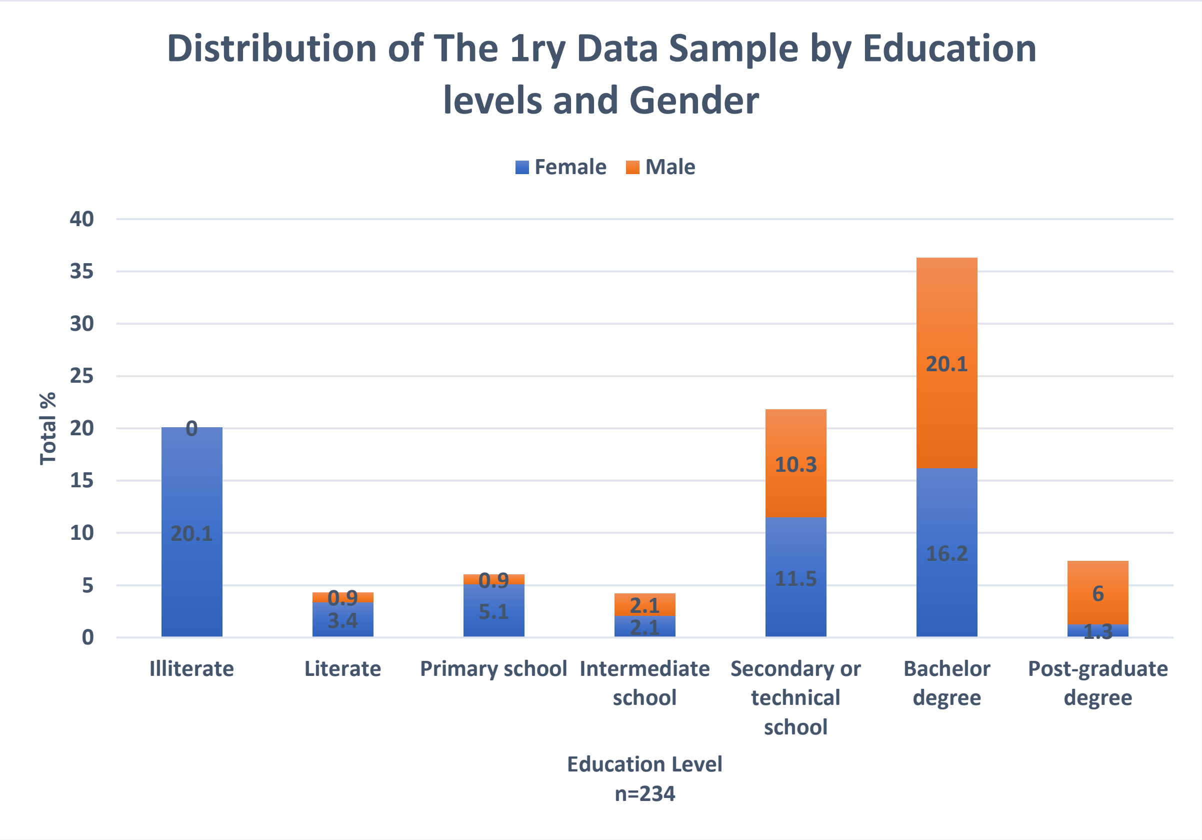

Figure 6.13: Primary data distribution for education levels by sex

Primary data sample distribution by Smoking status

The smoking status distribution by age group shows that smoking is highest in the age group 30-39 years followed by the age group 40-49 years (Figure 6.14). After the age of 39 years, smoking declines as the study sample ages. Regarding sex, smoking is more common among males than the females in the primary data sample (Figure 6.15).

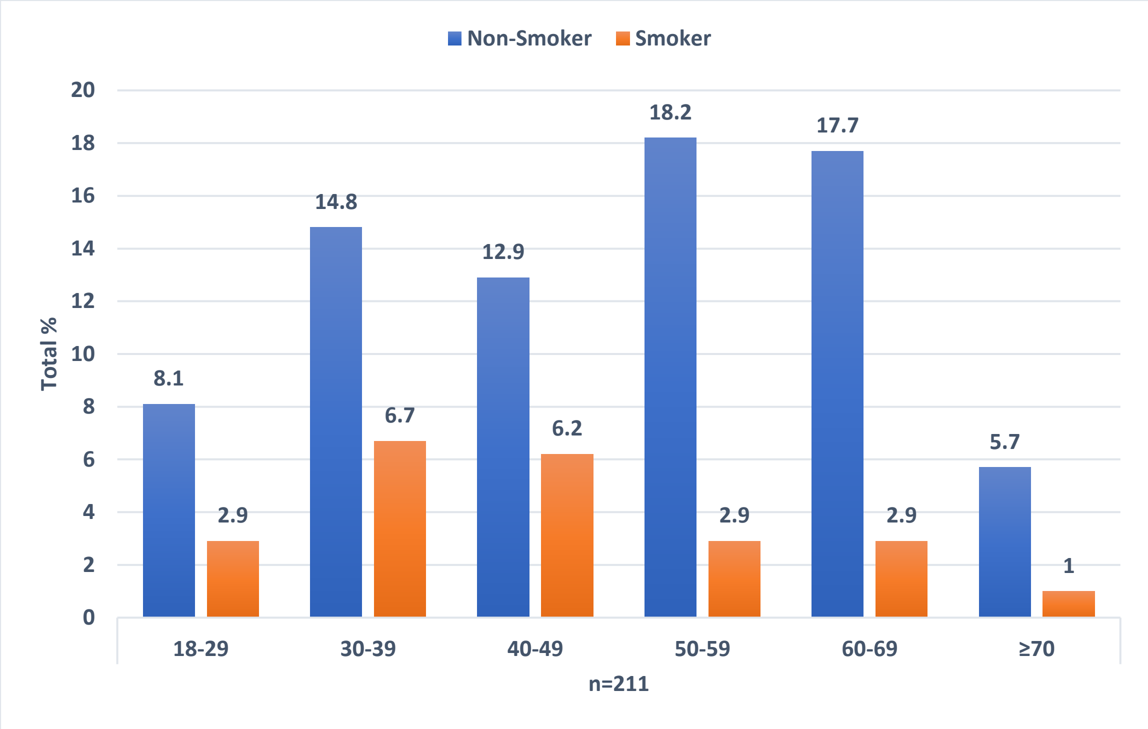

Figure 6.14: Primary data distribution for smoking status by age group

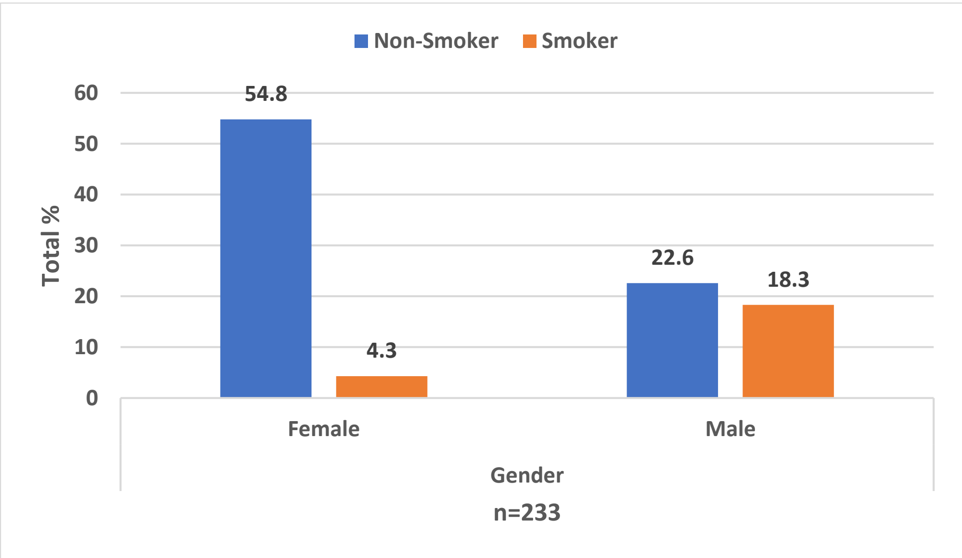

Figure 6.15: Primary data distribution for smoking status by sex

Primary data sample distribution by Physical activity

Unlike the secondary data sample, the physical activity distribution by age group and sex within the primary data sample shows a relatively high level of physical activity (Figures 6.16 and 6.17). Also, unlike the secondary data sample, in the primary data sample distribution, more females exercise in comparison to males. The difference between the primary and secondary data sample can be attributed to the question structure within the questionnaires. While the secondary data include information on physical activities in the form of exercise, the primary data questionnaire also included questions about other forms of physical activities including manual work in jobs.

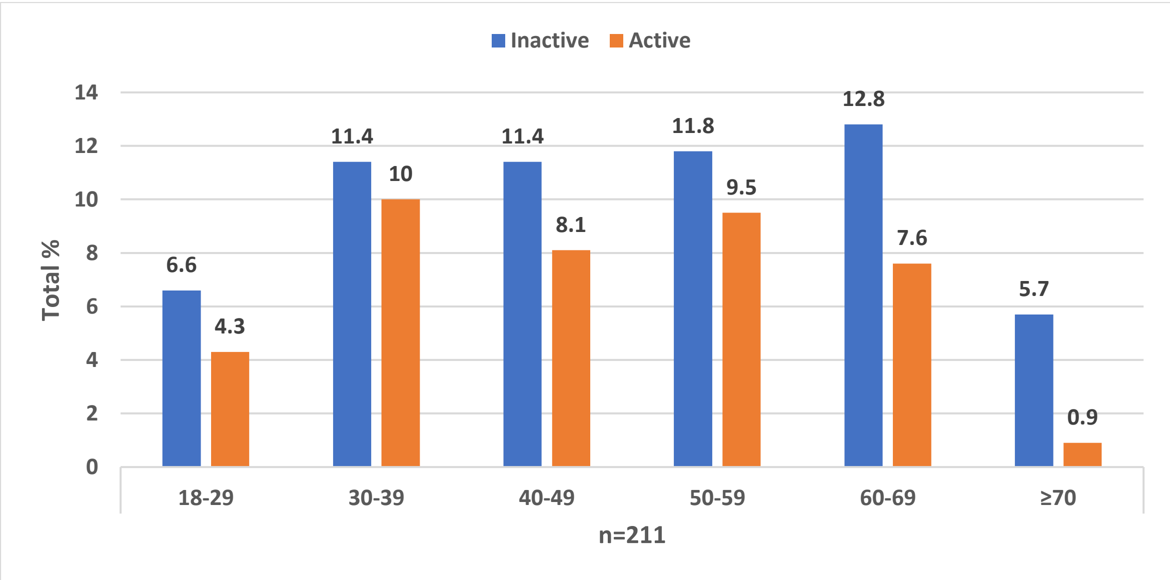

Figure 6.16: Primary data distribution for physical activity by age group

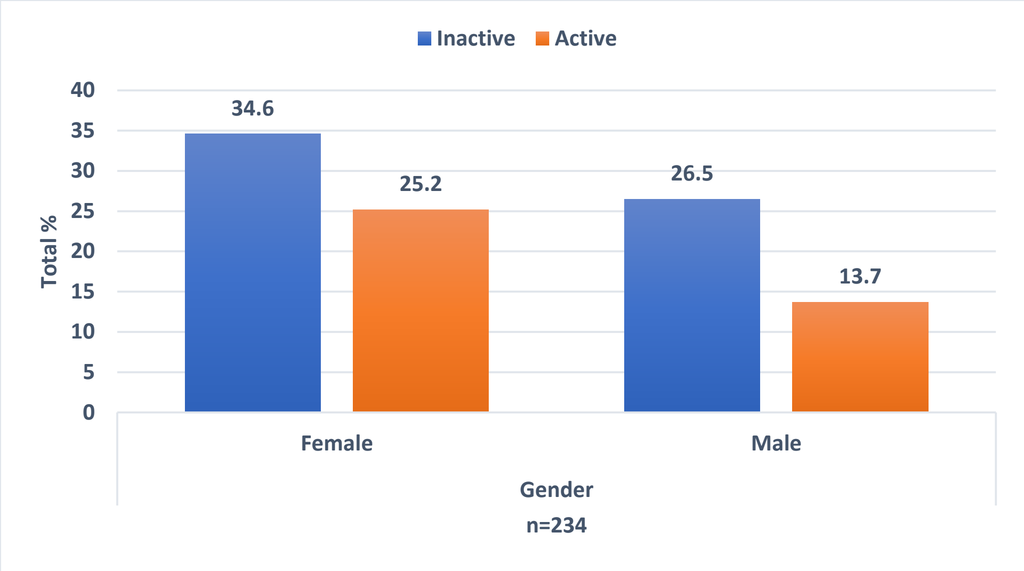

Figure 6.17: Primary data distribution for physical activity by sex

Primary data sample distribution by Having a history of chronic diseases other than T2D

The distribution of having chronic diseases including cardiovascular diseases, asthma or malignancies by age group shows an increase in the proportions of having chronic diseases as the age increases (Figure 6.18). Regarding sex, the females reported more history of having chronic diseases other than T2D compared to males within the primary data sample (Figure 6.19).

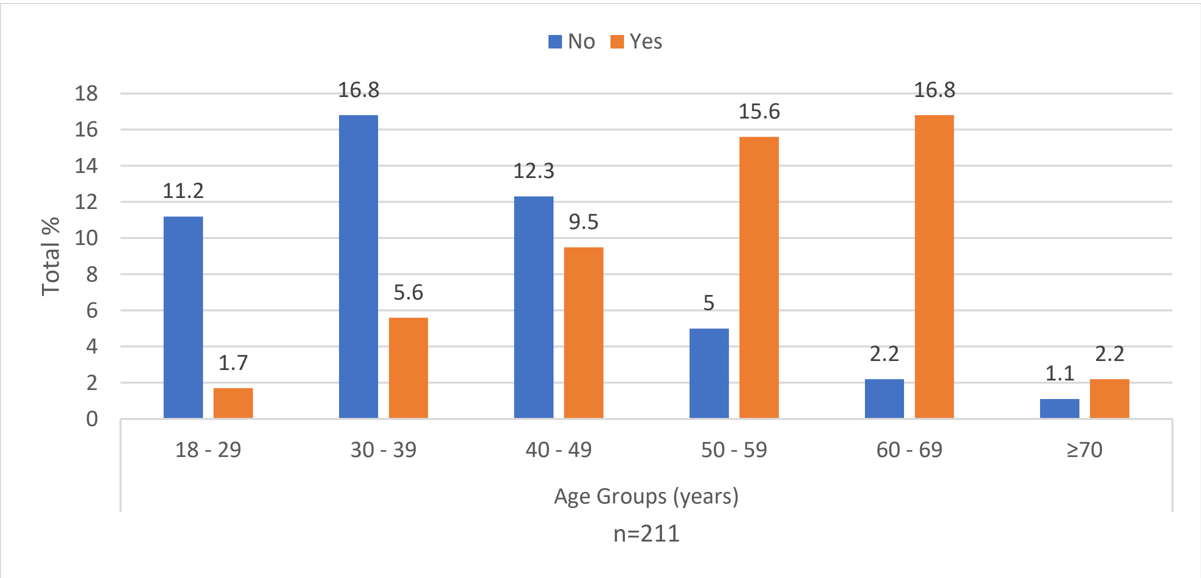

Figure 6.18: Primary data distribution for having reported a chronic disease other than T2D by age group

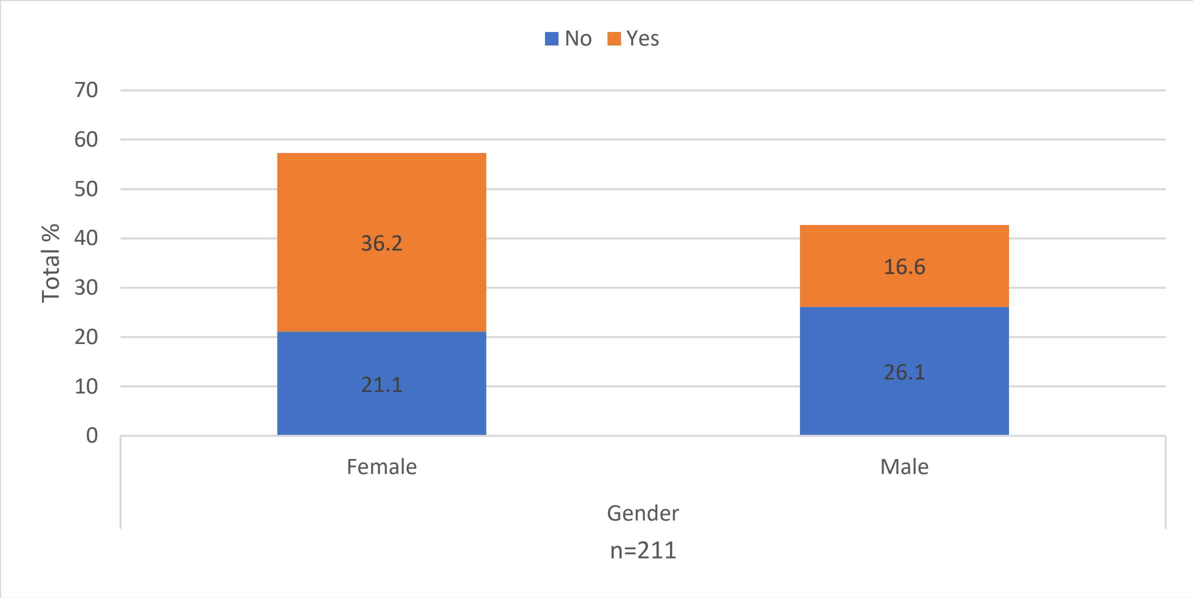

Figure 6.19: Primary data distribution for having reported a chronic disease other than T2D by sex

Primary data sample distribution by Having a family history of T2D

Having a family history of T2D was more commonly reported in the age group 30-39 years within the primary data sample (Figure 6.20). Most participants reported having a family history of T2D regardless of sex (Figure 6.21).

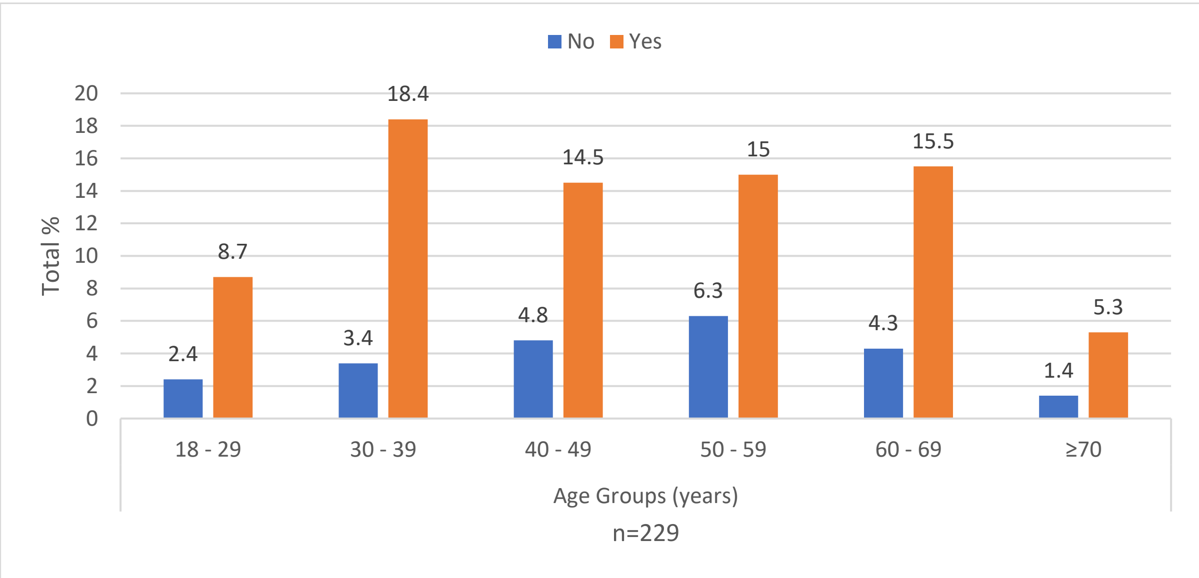

Figure 6.20: Primary data distribution for having reported a family history of T2D by age group

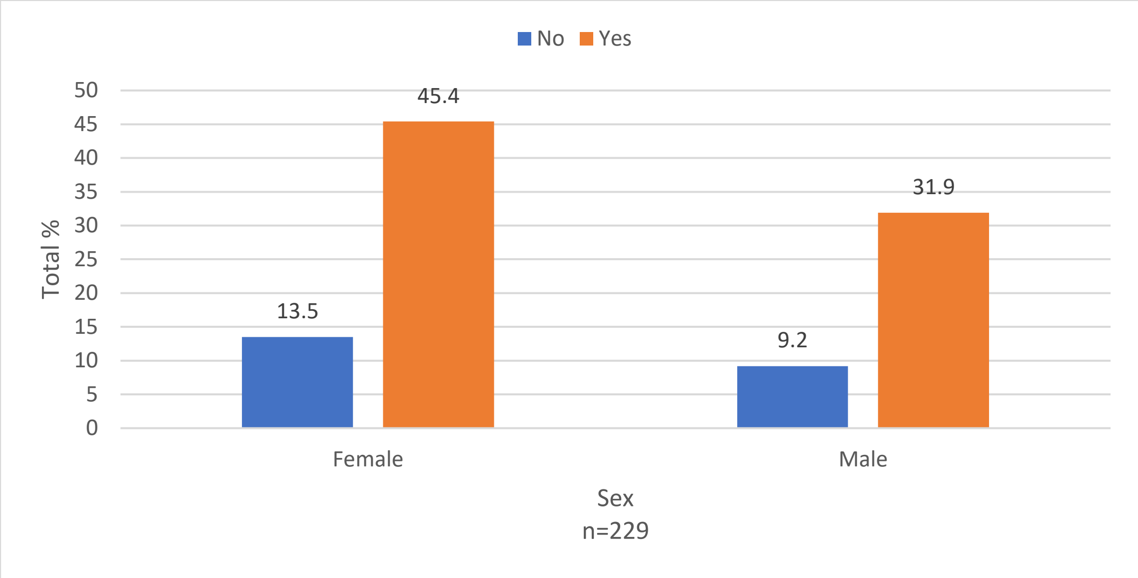

Figure 6.21: Primary data distribution for having reported a family history of T2D by sex

Primary data FFQ distribution by Age groups

The mean daily frequency of consumption of food items by age group can be seen in Figure 5.57. There are noticeable differences in the mean daily frequency of consumption of food items across all age groups. Those variations are more prominent for the dairy items, cold beverages, coffee and tea, vegetables and fruits. It is also notable that the older age groups (60 to 69 and 70 or above) consume fewer cold beverages compared to younger age groups.

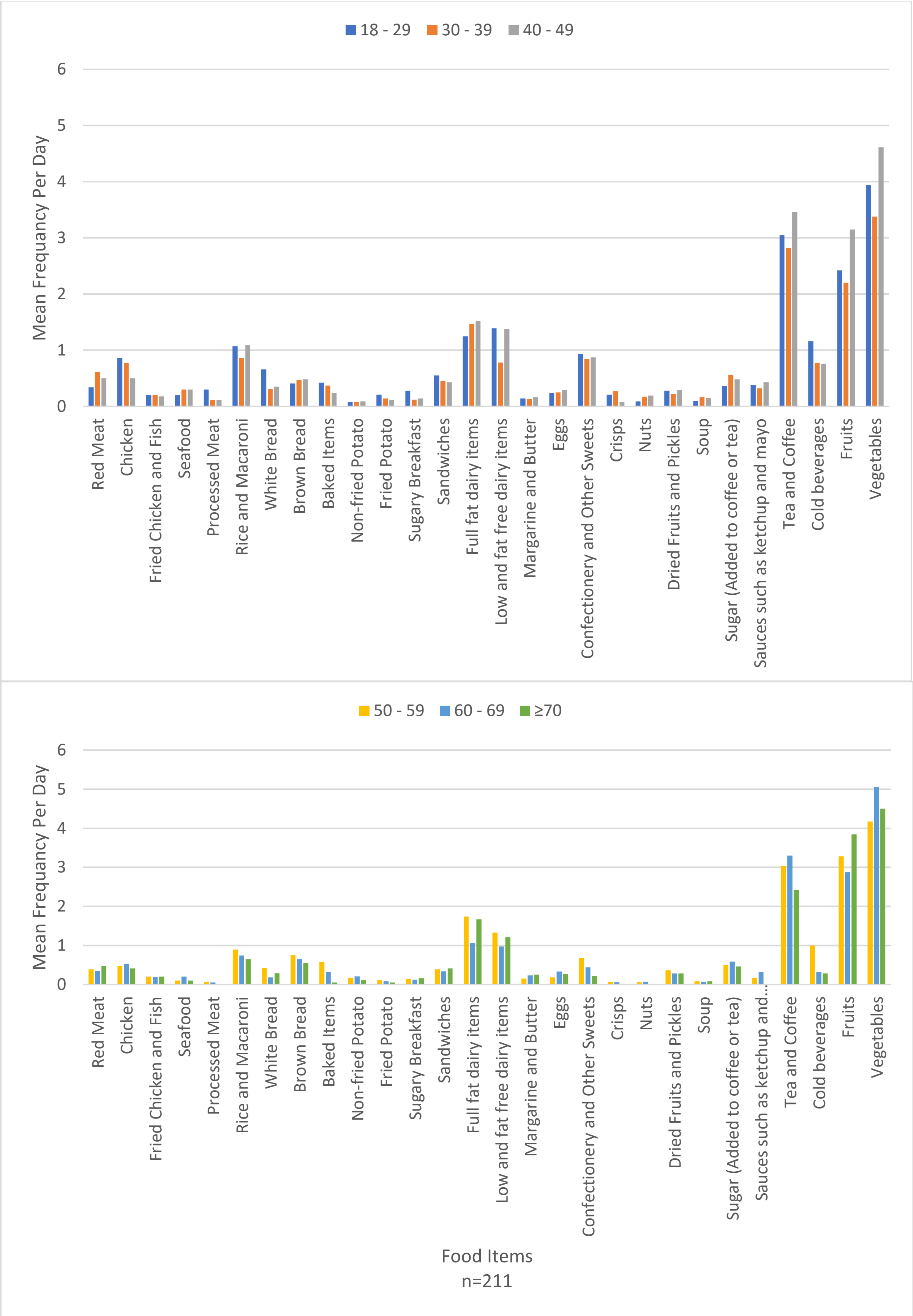

Figure 5.57: Mean frequency of consumption per day of the primary data FFQ food items by age group

Primary data FFQ distribution by Sex

Figure 5.58 displays the primary data mean daily frequency of consumption of food items by sex. Female participants reported consuming more fruit, vegetables and fewer cold beverages than males. Other than that, the patterns for both sexes are closely similar.

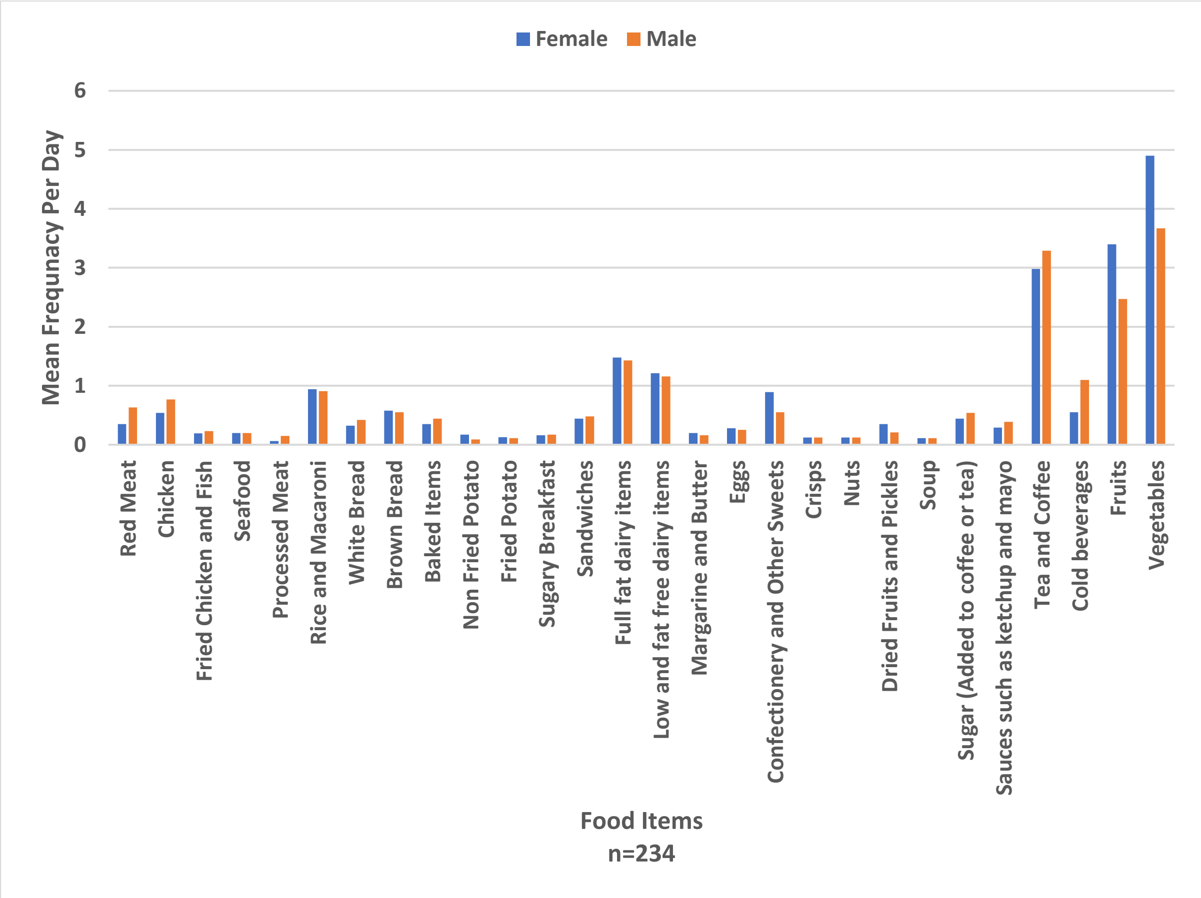

Figure 5.58: Mean frequency of consumption per day of the primary data FFQ food items by sex

Primary data FFQ distribution by Diagnosis groups

Regarding T2D diagnosis status, those with undiagnosed T2D reported consuming more rice and macaroni, white bread, low-fat dairy items, tea and coffee, cold beverages and fewer fruits and vegetables than the other two groups of non-diabetics and those diagnosed with T2D (Figure 5.59). Those with diagnosed T2D consumed fewer cold beverages than the other groups of non-diabetic and those with undiagnosed T2D. This decrease in cold beverages follows a similar pattern seen in the secondary data where there was a decrease in the consumption of carbonated drinks for those diagnosed with T2D.

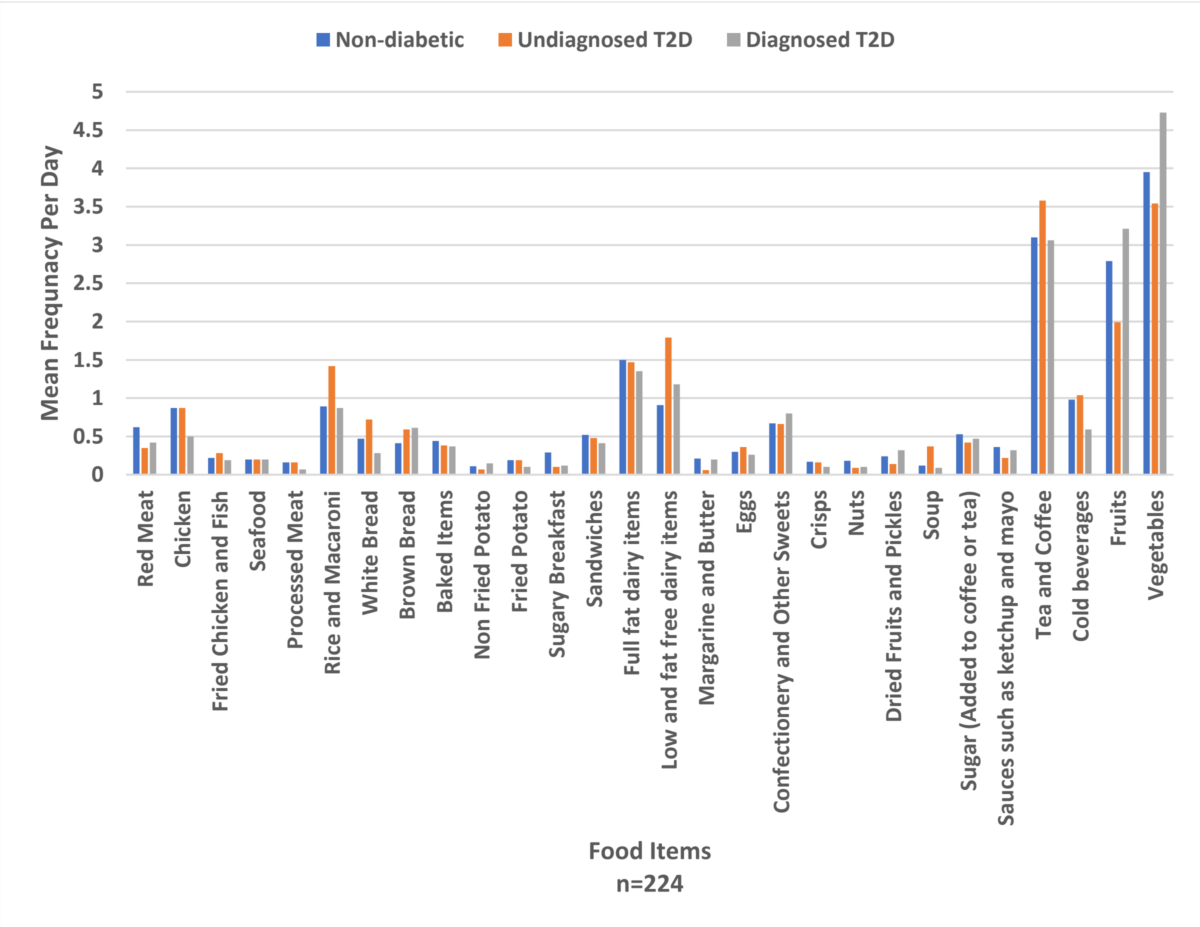

Figure 5.59: Mean frequency of consumption per day of the primary data FFQ food items by diagnosis groups

Primary data FFQ distribution by HbA1c level

Figure 5.60 shows the distribution of the mean daily frequency of consumption of food items by HbA1c diagnosis groups. Those with pre-diabetic levels of HbA1c reported consuming more vegetables, fruits, tea and coffee and full-fat dairy items than those with diabetic or normal levels of HbA1c.

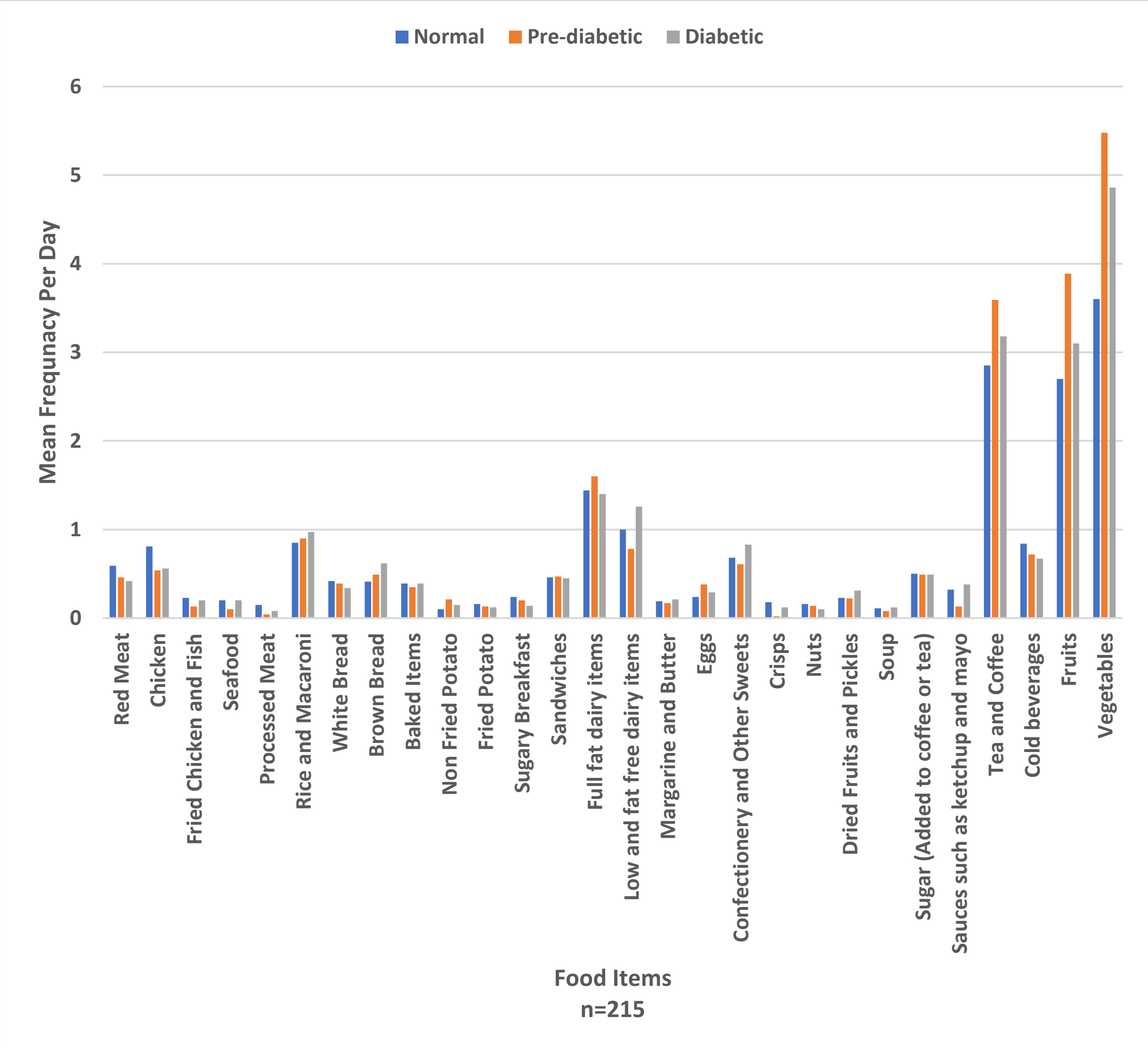

Figure 5.60: Mean frequency of consumption per day of the primary data FFQ food items by HbA1c diagnosis group

Primary data FFQ distribution by HbA1c level excluding those diagnosed with T2D

Excluding those diagnosed with T2D who are already taking blood glucose controlling medications from the HbA1c groups might help us to better understand the relationship between the single food items and HbA1c level. Figure 5.61 shows the primary data mean daily frequency of consumption of food items by HbA1c diagnosis groups excluding those diagnosed with T2D. Those with pre-diabetic levels of HbA1c also reported consuming more vegetables, fruits and tea and coffee than those with diabetic or normal levels of HbA1c, when, as before excluding those with a T2D diagnosis. However, after excluding those with a T2D diagnosis those with prediabetic levels of HbA1c consumed more cold beverages and fewer full-fat dairy items.

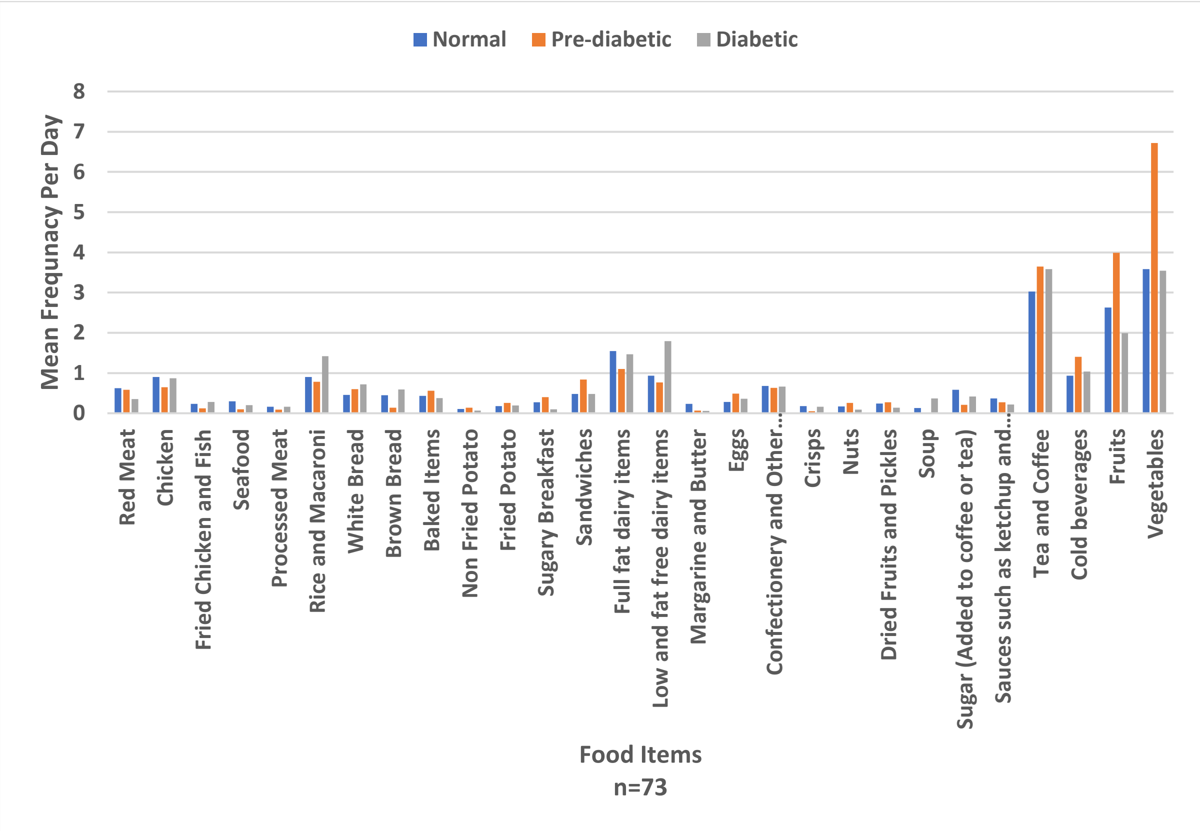

Figure 5.61: Mean frequency of consumption per day of the primary data FFQ food items by HbA1c diagnosis group excluding T2D

Primary data FFQ distribution by Body Mass Index levels

Figure 5.62 shows the primary data mean daily frequency of consumption of food items by BMI level. As the BMI level increases among participants, so does the mean daily consumption of fruits, tea and coffee and confectionary and other sweets. In comparison, the underweight participants reported consuming more brown bread, more low- and fat-free dietary items, more fruits and more vegetables then the other participants.

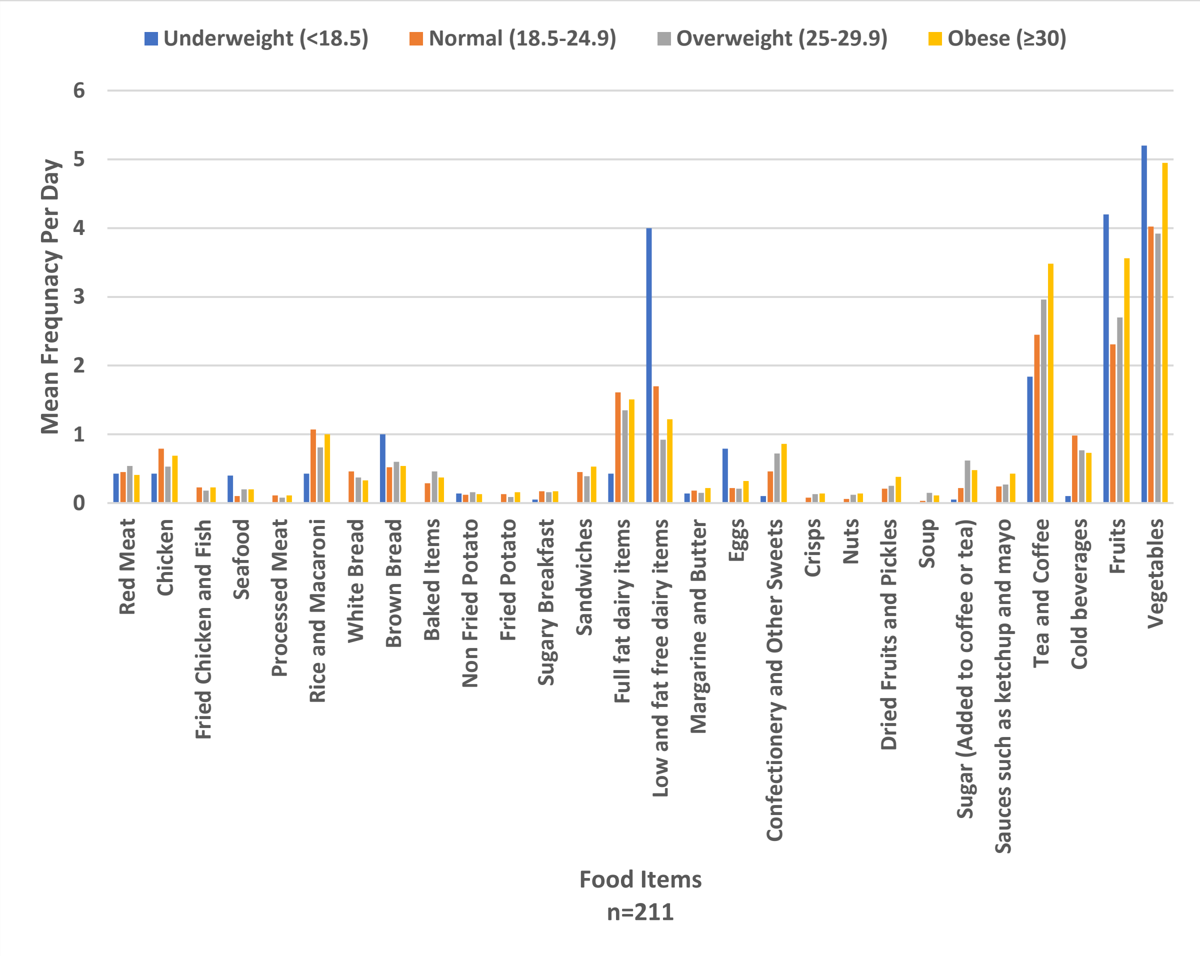

Figure 5.62: Mean frequency of consumption per day of the primary data FFQ food items by BMI level

Primary data FFQ distribution by Estimated monthly households' income

The distribution of the primary data means the daily frequency of consumption of food items by income levels shows that those with the lowest level of income (<5000 Saudi Riyals per month) consumed less tea and coffee compared to the main pattern seen in figure 5.56 (Figure 5.63). Those with the level income of 15,000 to 20,000 Saudi riyals per month consumed more fruits but less dried fruit. This suggests that there might be changes in the diet based on the socioeconomic status within the primary data sample.

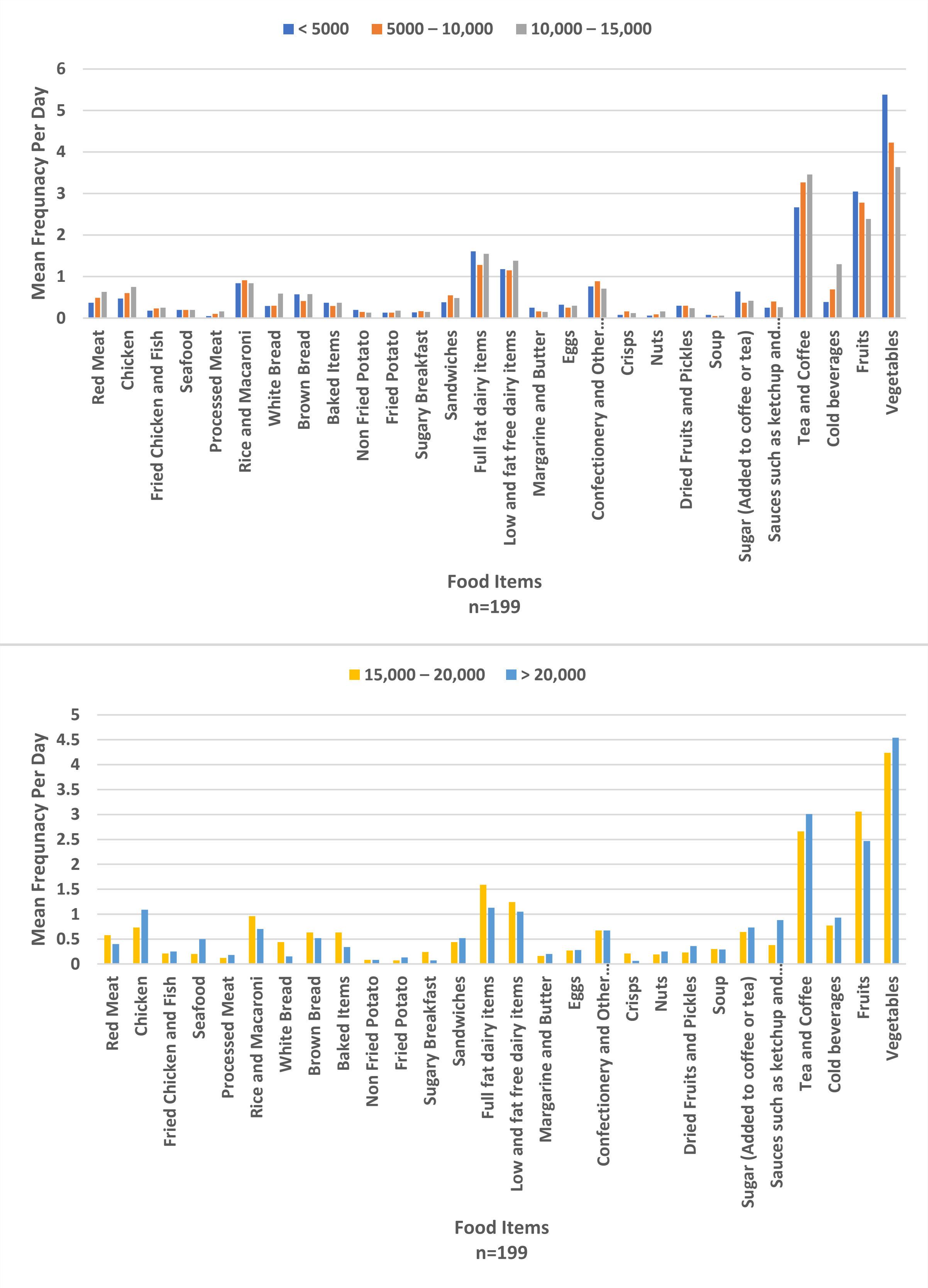

Figure 5.63: Mean frequency of consumption per day of the primary data FFQ food items by income level

Primary data FFQ distribution by Education level

Figure 5.64 shows the primary data mean daily frequency of consumption of food items by education levels. Compared to the main pattern seen in figure 5.56 those who are illiterate appears to be consuming fewer vegetables and less full-fat Dairy Products. In addition, those who are literate with no school education appears to be consuming less chicken and less tea and coffee. The other education levels follow a pattern of distribution that is similar to the population as a whole.

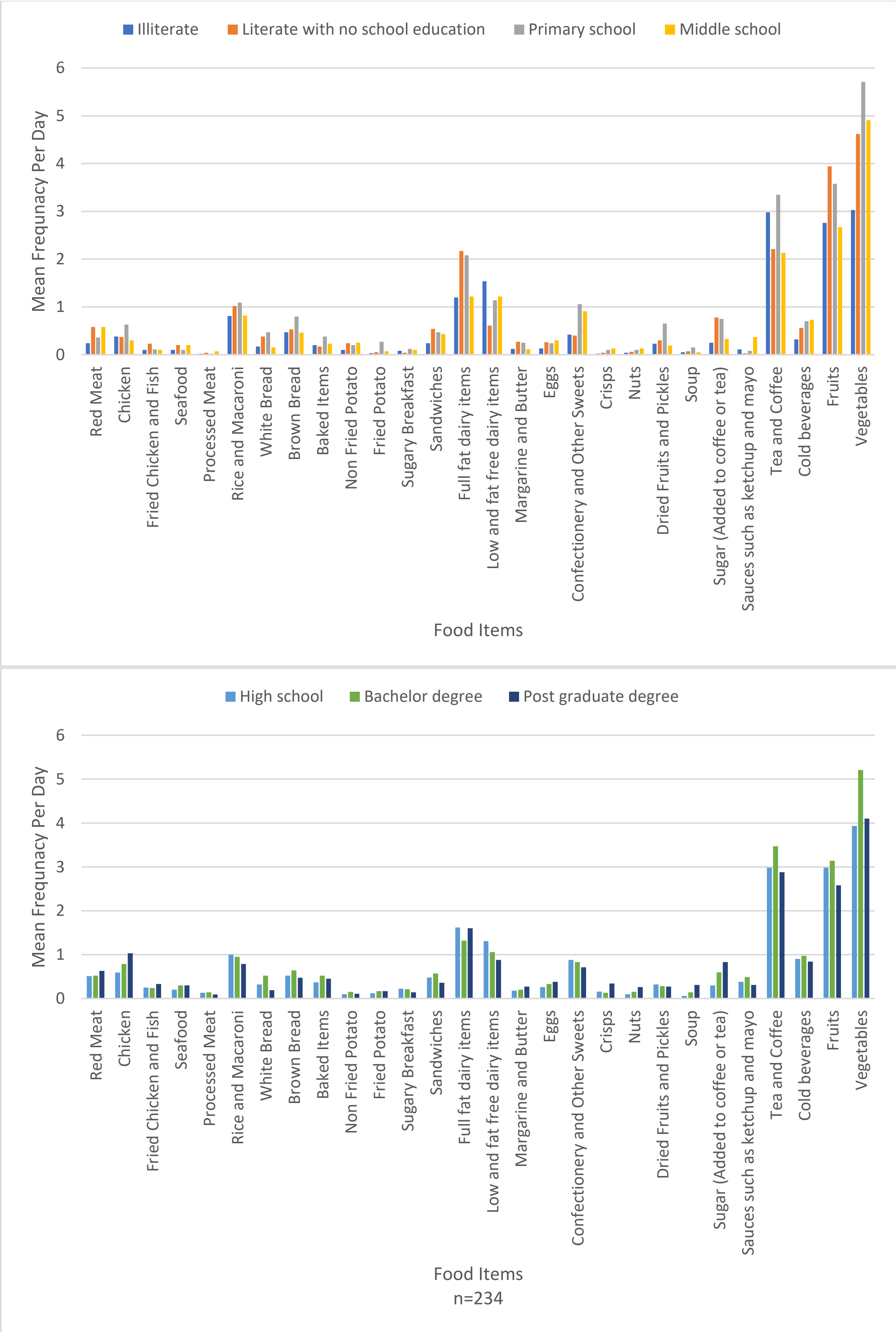

Figure 5.64: Mean frequency of consumption per day of the primary data FFQ food items by

Primary data FFQ distribution by Smoking status

The pattern for the distribution of the primary data means of the daily frequency of consumption of food items by smoking status can be seen in figure 5.65. It appears that both smokers and non-smokers followed a similar pattern of consumption.

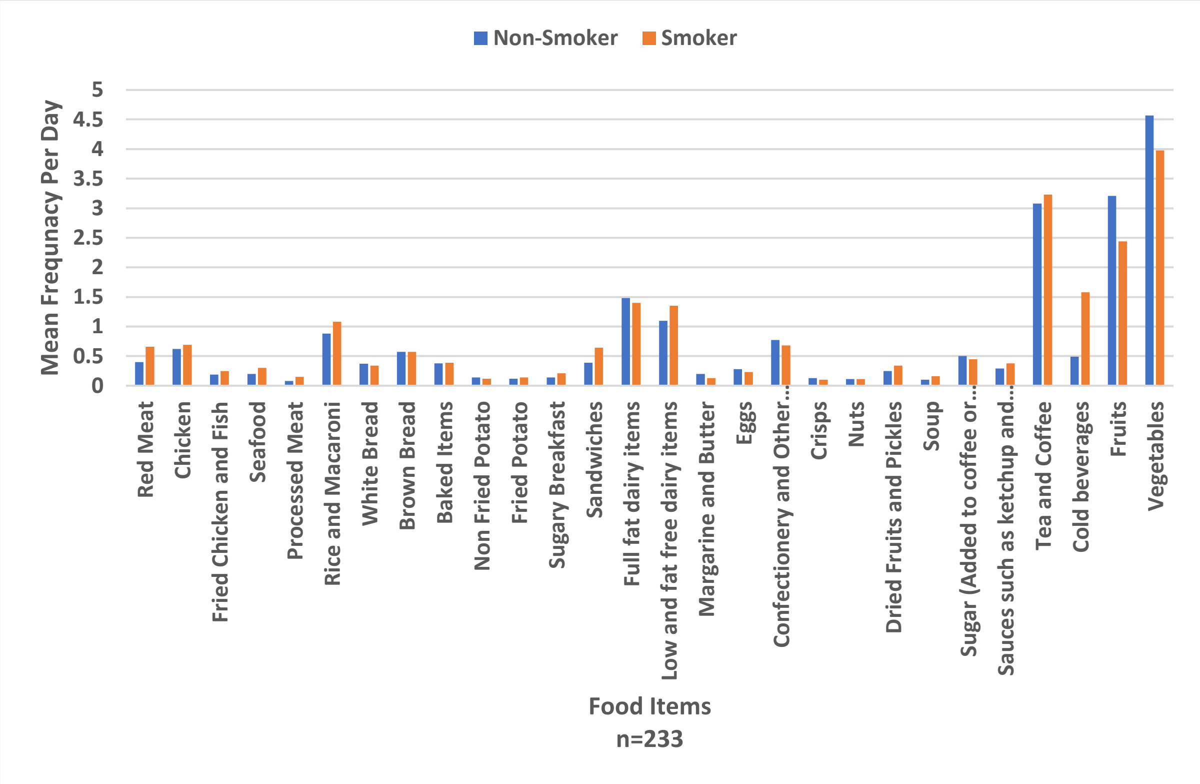

Figure 5.65: Mean frequency of consumption per day of the primary data FFQ food items by

Primary data FFQ distribution by Physical activities

The pattern for the distribution of the primary data means food items daily frequency of consumption by physical activity can be seen in figure 5.66. Both groups of physically active and inactive followed a similar pattern of consumption of the single food items as the one seen in the main distribution in figure 5.56.

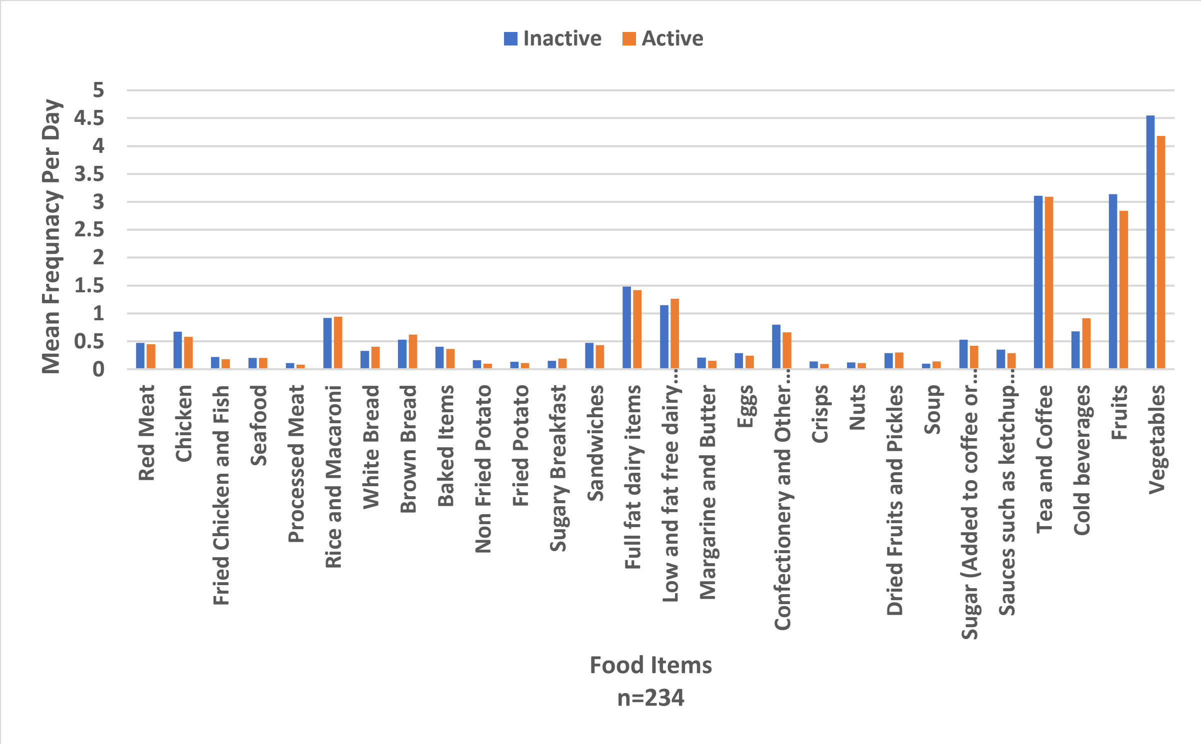

Figure 5.66: Mean frequency of consumption per day of the primary data FFQ food items by physical activity status

Primary data FFQ distribution by Having a history of chronic diseases other than T2D

The pattern for the distribution of the primary data means food items daily frequency of consumption by having a history of chronic disease other than T2D can be seen in figure 5.67. Both patterns for having or not having chronic diseases other than T2D follow a similar pattern to the one seen in the main figure of 5.56. This suggests that people might not be substantially changing their diet based on having a diagnosis of chronic disease.

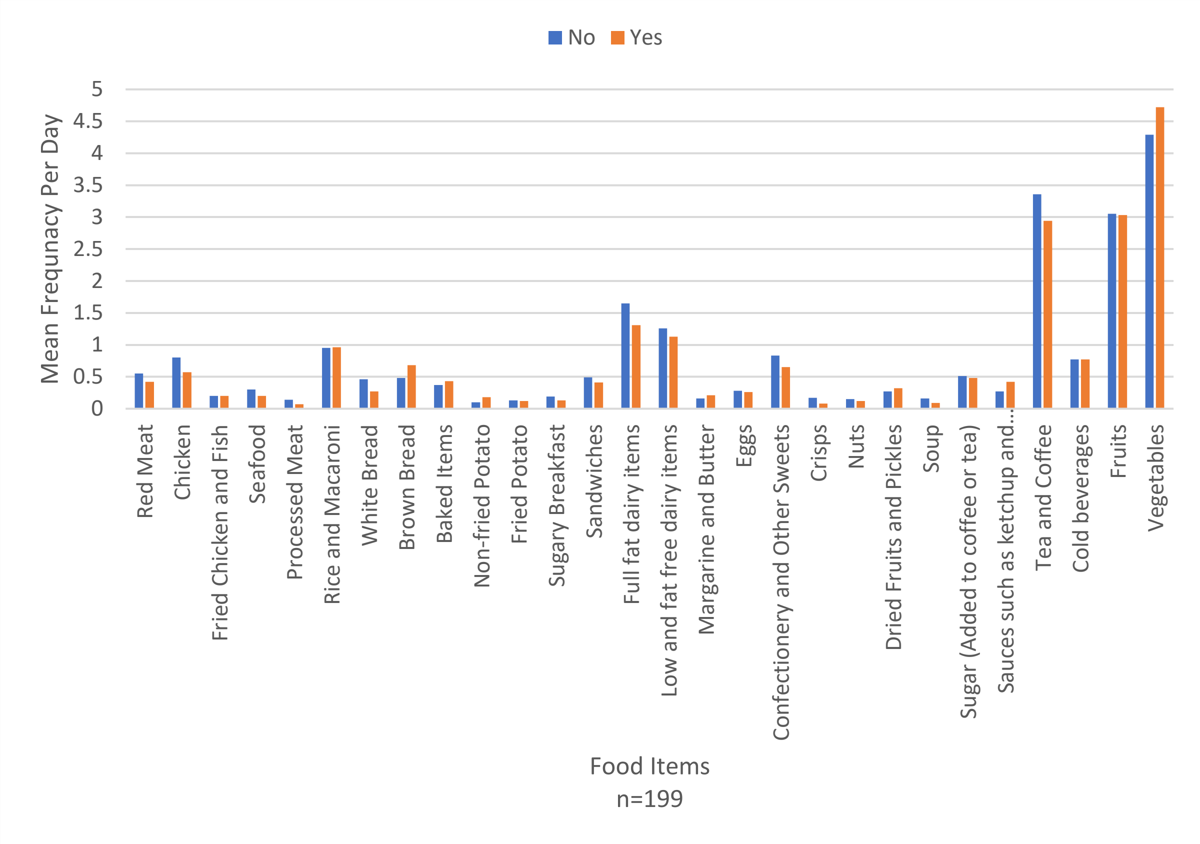

Figure 5.67: Mean frequency of consumption per day of the primary data FFQ food items by chronic disease status

Primary data dietary patterns association with Households monthly income estimates

Figure 6.31 and Table 6.14 show the distribution of the dietary pattern scores by household monthly income estimate. There are no major differences in the dietary pattern scores between those on a low income and those on a high income. ANOVA hypothesis testing also shows no statistically significant differences in the dietary pattern scores between the estimated monthly income levels.

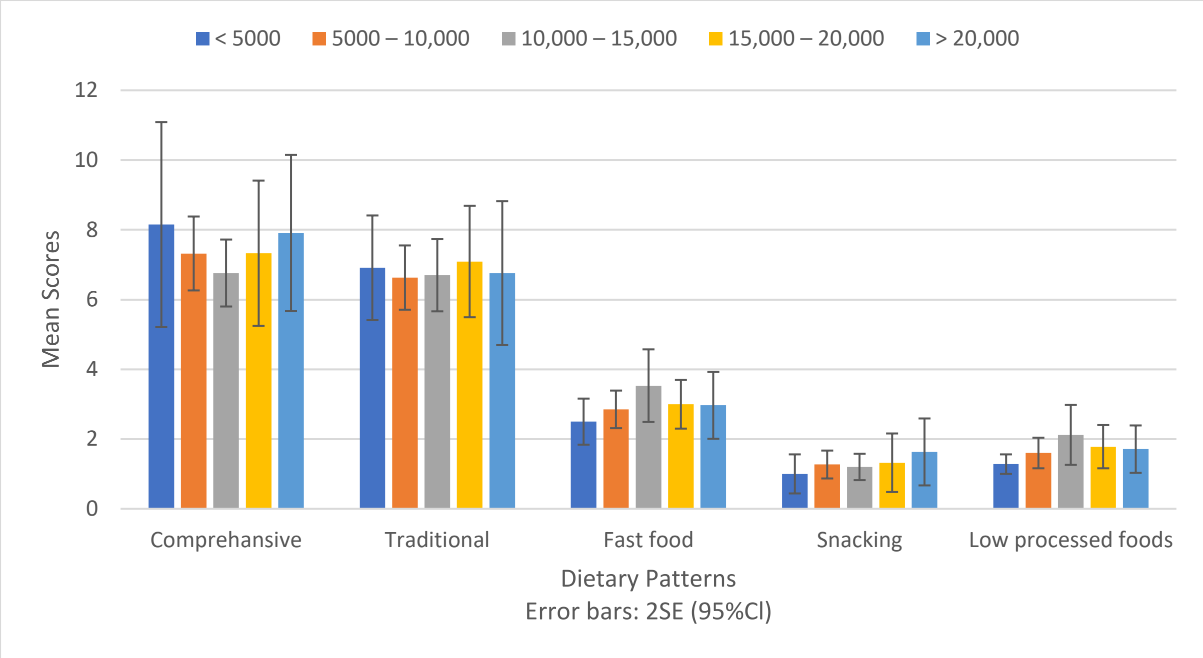

Figure 6.31: Primary data mean dietary pattern scores stratified by household estimated monthly income level in Saudi Riyals

Table 6.14: Primary data dietary pattern score means, standard deviations and ANOVA hypothesis tests stratified by household estimated monthly income level in Saudi Riyals

	< 5000		**5000 – 10,000**		**10,000 – 15,000**		**15,000 – 20,000**		**> 20,000**		***F* (p-value)***
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**		**SD**
Comprehensive	8.15	11.04	7.32	4.1	6.76	2.97	7.33	5.98	7.91	3.71	0.259 (0.904)
Traditional	6.91	5.61	6.63	3.6	6.7	3.25	7.09	4.59	6.76	3.42	0.076 (0.990)
Fast Food	2.5	2.45	2.85	2.06	3.53	3.24	3	2.04	2.97	1.6	1.066 (0.374)
Snacking	1	2.12	1.27	1.57	1.2	1.21	1.32	2.39	1.63	1.59	0.366 (0.832)
Low Processed Food	1.28	1.08	1.6	1.69	2.12	2.67	1.78	1.76	1.71	1.14	1.337 (0.258)

* One-way ANOVA hypothesis test

Primary data dietary patterns association with Education levels

On examining the distribution of the primary data dietary pattern scores by participant education level, participants who only had a primary school level of education scored higher means for the Comprehensive, Traditional and Fast Food dietary patterns. Participants who had a post-graduate level of education scored highest for the Snacking dietary pattern while participants with a high school level of education scored highest in the Low Processed Food dietary pattern (Figure 6.32 and Table 6.15).

Using ANOVA hypothesis test to find if there were differences between participants with different education levels in the mean dietary pattern scores, it was found that there were statistically significant differences for the Fast Food and Snacking dietary patterns (Table 6.15).

Post hoc tests revealed that the differences are only between participants who are illiterate and participants with a bachelor level of education for both the Fast Food (p=0.012) and Snacking (p=0.009) dietary patterns. For the Fast Food dietary pattern, participants with a bachelor level of education had a higher mean than participants who were illiterate (mean (SD) = 3.45 (2.82) and 1.96 (1.58) respectively). For the Snacking dietary pattern, participants with a bachelor level of education also had a higher mean than participants who were illiterate (mean (SD) = 1.47 (2.05) and 0.32 (0.98) respectively).

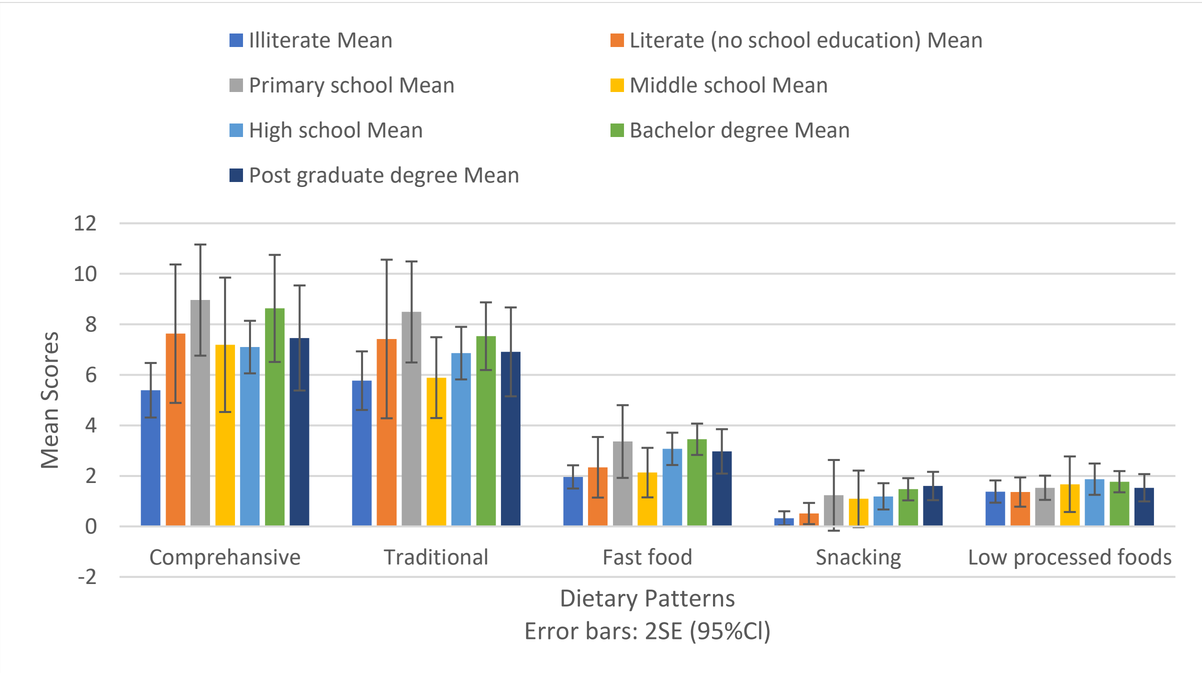

Figure 6.32: Primary data mean dietary pattern scores stratified by participant education level

Table 6.15: Primary data dietary pattern score means, standard deviations and ANOVA hypothesis tests stratified by participant education level

	Illiterate		Literate with no school education		Primary school		Middle school		High school		Bachelor degree		Postgraduate degree		*F* (p-value)
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	
Comprehensive	5.39	3.69	7.63	4.34	8.96	4.11	7.19	4.21	7.1	3.73	8.63	9.73	7.46	4.28	1.336 (0.242)
Traditional	5.77	4.01	7.42	4.95	8.49	3.75	5.89	2.53	6.86	3.69	7.53	6.15	6.91	3.61	1.018 (0.414)
Fast Food	1.96	1.58	2.34	1.9	3.36	2.71	2.13	1.56	3.07	2.32	3.45	2.82	2.97	1.83	**2.433 (0.027)**
Snacking	0.32	0.98	0.51	0.65	1.23	2.6	1.09	1.78	1.19	1.86	1.47	2.05	1.6	1.14	**2.591 (0.019)**
Low Processed Food	1.38	1.5	1.36	0.93	1.53	0.91	1.67	1.74	1.87	2.21	1.77	1.97	1.53	1.12	0.426 (0.861)

* One way ANOVA hypothesis test

Primary data dietary patterns association with Smoking status association with the primary data dietary patterns

Figure 5.25 and Table 5.27 explore the relationship between smoking status and the primary data dietary pattern scores. While non-smokers scored a higher mean for the Comprehensive and a slightly higher mean for the Traditional dietary patterns, participants who were currently smoking had higher means for the Fast Food, Snacking and Low Processed Food dietary patterns.

Hypothesis testing revealed that participants who scored high in the Low Processed food dietary pattern had statistically significant higher odds of being smokers (OR (95%CI=1.423 (1.116-1.737)). This significant association also continues to be significant after adjusting for age and sex (OR (95%CI=1.325 (1.045-1.679)) (Table 5.27).

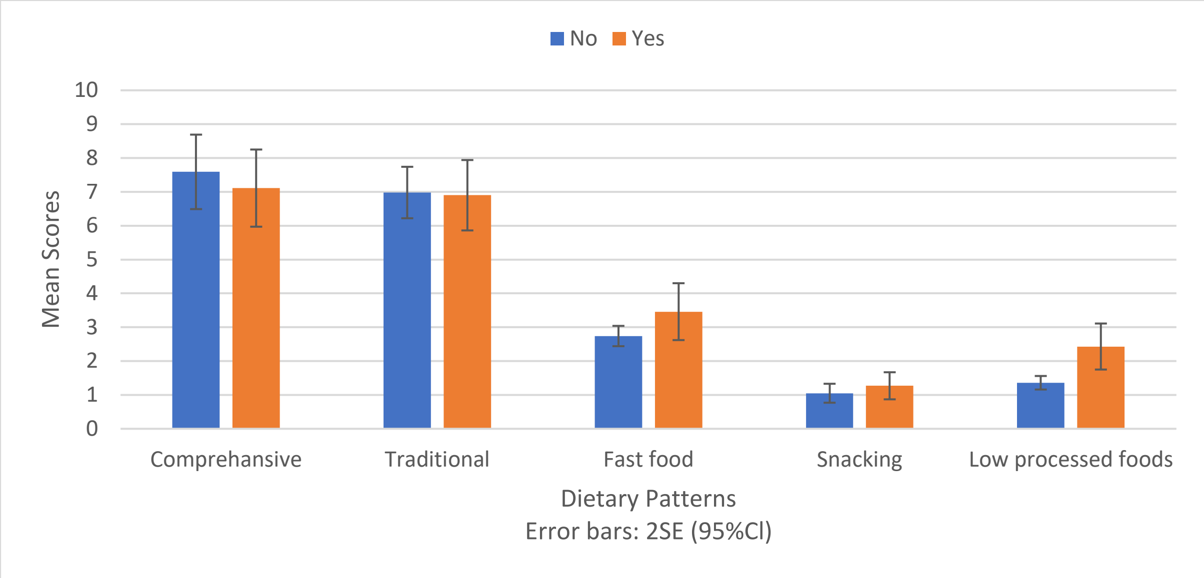

Figure 5.25: Primary data mean dietary pattern scores stratified by participant smoking status

Table 5.27: Primary data dietary pattern score mean, standard deviation and odds ratio results stratified by participant smoking status

	Non-smoker		Current smoker		OR (95%CI) of being Smoker	
	M	**SD**	**M**	**SD**	**Model 1***	**Model 2****
Comprehensive	7.59	7.29	7.11	4.14	0.988 (0.935-1.043)	0.986 (0.900-1.081)
Traditional	6.98	5.1	6.9	3.73	0.996 (0.933-1.063)	1.005 (0.914-1.106)
Fast Food	2.74	2.06	3.46	3.01	1.128 (0.997-1.276)	1.071 (0.917-1.257)
Snacking	1.05	1.85	1.27	1.44	1.069 (0.907-1.261)	1.042 (0.831-1.306)
Low Processed Food	1.36	1.29	2.43	2.46	**1.423 (1.116-1.737)**	**1.325 (1.045-1.679)**

* Unadjusted, **Adjusted to age and sex

Primary data dietary patterns association with Physical activity association with the primary data dietary patterns

By exploring the distribution of the dietary pattern scores by exercising regularly, participants who reported no regular exercise scored higher for the Comprehensive, Traditional and Snacking dietary patterns. Participants who exercise regularly scored slightly higher for the Low Processed food dietary patterns. Both those who exercise regularly or not scored similar scores for the Fast Food dietary pattern (Figure 5.26 and Table 5.28). Hypothesis testing revealed no statistically significant association between dietary pattern scores and physical activity.

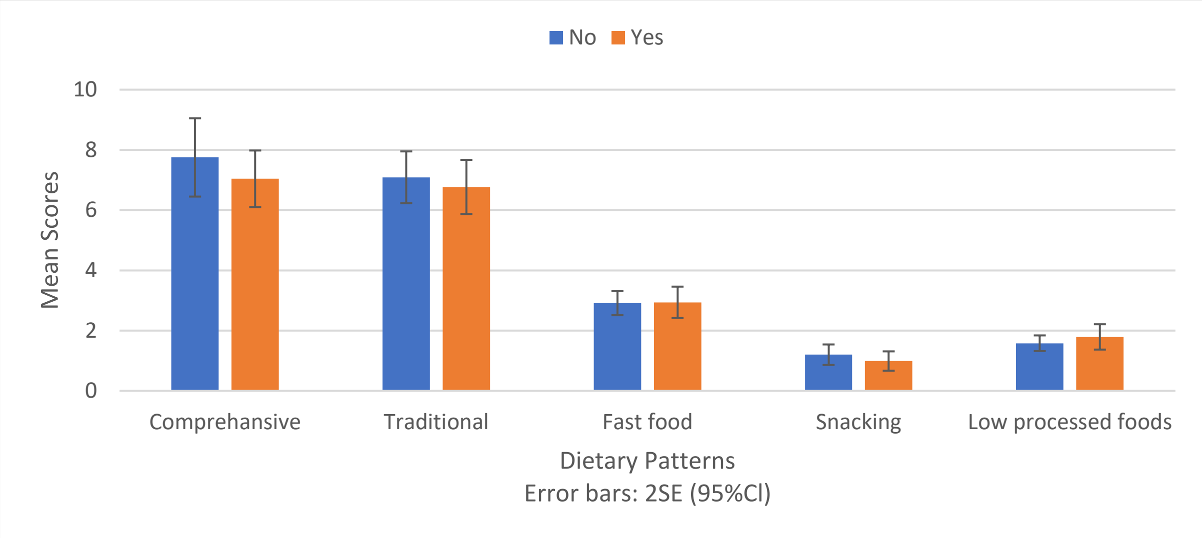

Figure 5.26: Primary data mean dietary pattern scores stratified by participant physical activity

Table 5.28: Primary data dietary patterns score mean, standard deviation and odds ratio results stratified by participant physical activity

	Exercise Regularly					
	No		**Yes**		**OR (95%CI) of exercising regularly**	
	M	**SD**	**M**	**SD**	**Model 1***	**Model 2****
Comprehensive	7.75	7.78	7.04	4.53	0.982 (0.937-1.029)	0.974 (0.918-1.033)
Traditional	7.09	5.15	6.77	4.26	0.986 (0.932-1.043)	0.925 (0.932-1.066)
Fast Food	2.91	2.37	2.94	2.45	1.006 (0.901-1.122)	1.018 (0.896-1.156)
Snacking	1.2	1.98	0.99	1.48	0.935 (0.801-1.090)	0.886 (0.736-1.066)
Low Processed Food	1.58	1.61	1.79	2.04	1.068 (0.924-1.235)	1.159 (0.976-1.377)

* Unadjusted, **Adjusted to age and sex

Primary data dietary patterns association with having a history of chronic diseases other than T2D association with the primary data dietary patterns

Figure 5.27 and Table 5.29 explore the relationship between the dietary pattern scores and the participants having a history of chronic diseases other than T2D. Participants who have no history of chronic diseases other than T2D scored higher for the Traditional, Fast Food and Snacking dietary patterns. However, hypothesis testing reports no statistically significant differences in dietary pattern scores between participants based on having a diagnosis of chronic diseases other than T2D.

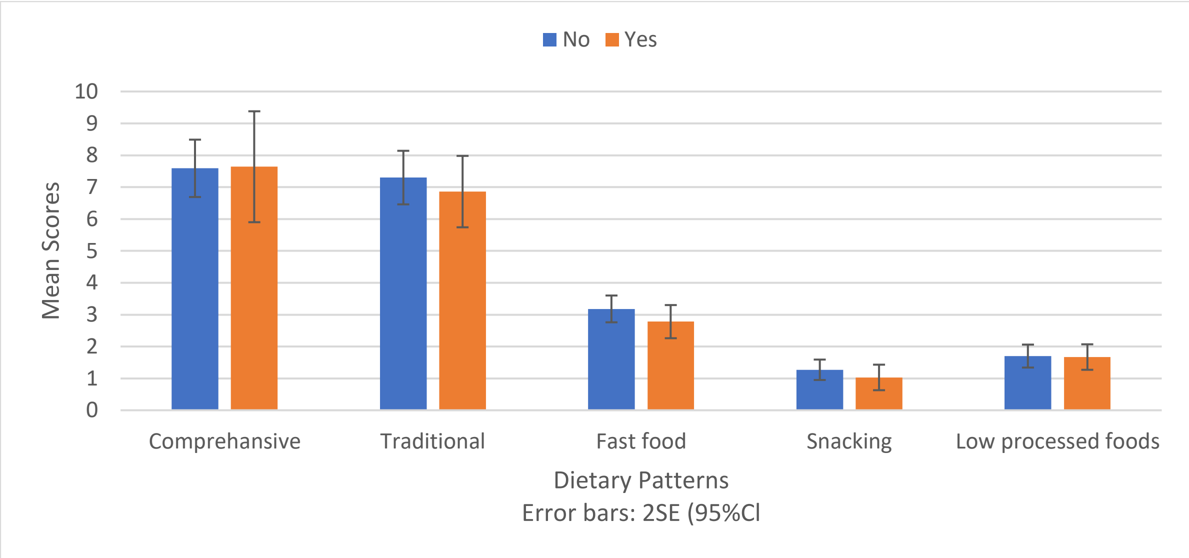

Figure 5.27: Primary data mean dietary pattern scores stratified by a participant having a history of chronic diseases other than T2D

Table 5.29: Primary data dietary pattern score mean, standard deviation and odds ratio results stratified by participants having a history of chronic disease other than T2D

	Having a history of chronic disease other than T2D				**OR (95%CI) of exercising regularly**	
	No		**Yes**			
	M	**SD**	**M**	**SD**	**Model 1***	**Model 2****
Comprehensive	7.59	4.39	7.64	8.87	1.002 (0.960 - 1.045)	0.977 (0.932-1.024)
Traditional	7.3	4.08	6.86	5.72	0.971 (0.906 - 1.040)	0.931 (0.861 - 1.007)
Fast Food	3.18	2.08	2.78	2.69	0.939 (0.824-1.070)	1.017 (0.874 - 1.184)
Snacking	1.27	1.58	1.03	2	0.926 (0.782-1.095)	1.012 (0.831 - 1.233)
Low Processed Food	1.7	1.7	1.67	2.02	0.978 (0.826-1.157)	1.046 (0.862 - 1.269)

* Unadjusted, **Adjusted to age and sex

Other descriptive analyses for the primary data showing mean frequency of consumption per day stratified by different demographic and health variables

	Age Groups (years)											
	18 - 29		30 - 39		40 - 49		50 - 59		60 - 69		≥70	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Red Meat	0.34	0.33	0.61	0.83	0.5	0.51	0.39	0.47	0.35	0.38	0.47	0.3
Chicken	0.86	0.53	0.77	0.62	0.5	0.46	0.47	0.4	0.52	0.53	0.41	0.35
Fried Chicken and Fish	0.2	0.27	0.2	0.27	0.18	0.21	0.2	0.22	0.19	0.53	0.2	0.35
Seafood	0.2	0.3	0.3	0.4	0.3	0.4	0.1	0.3	0.2	0.8	0.1	0.1
Processed Meat	0.3	0.45	0.11	0.15	0.11	0.25	0.07	0.12	0.05	0.2	0	0.01
Rice and Macaroni	1.07	0.92	0.86	1.24	1.09	0.96	0.89	0.7	0.74	0.51	0.65	0.68
White Bread	0.66	0.93	0.31	0.58	0.35	0.82	0.42	0.67	0.18	0.34	0.29	0.47
Brown Bread	0.41	0.58	0.47	0.6	0.48	0.7	0.75	1.07	0.65	0.74	0.55	0.48
Baked Items	0.42	0.45	0.37	0.36	0.24	0.36	0.58	1.69	0.31	0.61	0.05	0.09
Non-fried Potato	0.08	0.21	0.08	0.14	0.09	0.17	0.17	0.42	0.21	0.39	0.11	0.23
Fried Potato	0.21	0.22	0.14	0.2	0.11	0.19	0.11	0.23	0.08	0.21	0.05	0.12
Sugary Breakfast	0.28	0.6	0.12	0.2	0.14	0.3	0.14	0.26	0.12	0.47	0.16	0.27
Sandwiches	0.55	0.6	0.45	0.48	0.43	0.4	0.39	0.4	0.34	0.65	0.41	0.54
Full fat dairy items	1.25	1.12	1.47	1.14	1.52	1.34	1.74	1.91	1.06	0.74	1.67	1.66

Low and fat free dairy items	1.39	1.41	0.78	1.24	1.38	1.71	1.33	2.32	0.97	1.19	1.21	1.29
Margarine and Butter	0.14	0.21	0.13	0.22	0.16	0.31	0.15	0.28	0.23	0.86	0.25	0.48
Eggs	0.24	0.29	0.25	0.31	0.29	0.48	0.18	0.29	0.33	0.92	0.27	0.34
Confectionery and Other Sweets	0.93	1.17	0.84	1.23	0.87	1.4	0.68	0.89	0.44	0.83	0.22	0.24
Crisps	0.21	0.29	0.27	0.75	0.08	0.25	0.07	0.17	0.06	0.19	0	0
Nuts	0.09	0.16	0.17	0.27	0.19	0.32	0.06	0.1	0.07	0.14	0.02	0.04
Dried Fruits and Pickles	0.28	0.36	0.22	0.26	0.29	0.45	0.36	0.52	0.28	0.6	0.28	0.44
Soup	0.1	0.21	0.16	0.67	0.15	0.43	0.08	0.19	0.07	0.18	0.08	0.15
Sugar (Added to coffee or tea)	0.36	0.59	0.56	1.13	0.48	0.88	0.5	0.81	0.59	1.76	0.46	0.88
Sauces such as ketchup and mayo	0.38	0.41	0.32	0.38	0.43	1.4	0.17	0.5	0.32	0.94	0	0.01
Tea and Coffee	3.05	2.77	2.82	1.99	3.46	3.32	3.03	2.96	3.3	4.17	2.42	1.77
Cold beverages	1.16	1.26	0.77	0.97	0.76	1.58	1	3.13	0.31	0.41	0.28	0.38
Fruits	2.42	1.95	2.2	1.98	3.15	2.18	3.28	2.48	2.88	2.68	3.84	2.63
Vegetables	3.94	2.83	3.38	3.05	4.61	3.82	4.17	3.05	5.05	9.41	4.5	3.14

	Sex			
	Female		**Male**	
	M	**SD**	**M**	**SD**
Red Meat	0.35	0.42	0.63	0.68

Chicken	0.54	0.57	0.77	0.8
Fried Chicken and Fish	0.19	0.35	0.23	0.36
Seafood	0.2	0.4	0.2	0.5
Processed Meat	0.06	0.15	0.15	0.3
Rice and Macaroni	0.94	0.96	0.91	1.03
White Bread	0.32	0.54	0.42	0.83
Brown Bread	0.58	0.68	0.55	0.89
Baked Items	0.35	0.57	0.44	1.21
Non Fried Potato	0.17	0.36	0.09	0.15
Fried Potato	0.13	0.24	0.11	0.18
Sugary Breakfast	0.16	0.38	0.17	0.43
Sandwiches	0.44	0.62	0.48	0.55
Full fat dairy items	1.48	1.43	1.43	1.3
Low and fat-free dairy items	1.21	1.46	1.16	2.01
Margarine and Butter	0.2	0.57	0.16	0.27
Eggs	0.28	0.6	0.25	0.33
Confectionery and Other Sweets	0.89	1.48	0.55	0.7
Crisps	0.12	0.31	0.12	0.48
Nuts	0.12	0.23	0.12	0.21
Dried Fruits and Pickles	0.35	0.56	0.21	0.31
Soup	0.11	0.28	0.11	0.48
Sugar (Added to coffee or tea)	0.44	0.79	0.54	1.42
Sauces such as ketchup and mayo	0.29	0.9	0.39	0.79
Tea and Coffee	2.98	3.19	3.29	2.63
Cold beverages	0.55	0.89	1.1	2.47
Fruits	3.4	3.92	2.47	2.31
Vegetables	4.9	5.98	3.67	3.66

	Diagnosis group					
	Non-diabetic		Undiagnosed T2D		Diagnosed T2D	
	M	SD	M	SD	M	SD
Red Meat	0.62	0.78	0.35	0.5	0.42	0.43
Chicken	0.87	0.89	0.87	0.83	0.5	0.54
Fried Chicken and Fish	0.22	0.38	0.28	0.31	0.19	0.34
Seafood	0.2	0.4	0.2	0.3	0.2	0.5
Processed Meat	0.16	0.3	0.16	0.23	0.07	0.18
Rice and Macaroni	0.89	0.91	1.42	2.09	0.87	0.83
White Bread	0.47	0.81	0.72	1.2	0.28	0.54
Brown Bread	0.41	0.61	0.59	0.7	0.61	0.81
Baked Items	0.44	0.58	0.38	0.35	0.37	1.03
Non-fried Potato	0.11	0.2	0.07	0.15	0.15	0.34
Fried Potato	0.19	0.22	0.19	0.25	0.1	0.21
Sugary Breakfast	0.29	0.58	0.1	0.11	0.12	0.33
Sandwiches	0.52	0.58	0.48	0.51	0.41	0.6
Full fat dairy items	1.5	1.2	1.47	1.48	1.35	1.39
Low and fat free dairy items	0.91	1.28	1.79	2.63	1.18	1.62
Margarine and Butter	0.21	0.37	0.06	0.12	0.2	0.54
Eggs	0.3	0.33	0.36	0.33	0.26	0.59
Confectionery and Other Sweets	0.67	0.67	0.66	0.82	0.8	1.46
Crisps	0.17	0.6	0.16	0.28	0.1	0.3
Nuts	0.18	0.27	0.09	0.21	0.1	0.2
Dried Fruits and Pickles	0.24	0.45	0.14	0.18	0.32	0.51
Soup	0.12	0.33	0.37	1.24	0.09	0.2
Sugar (Added to coffee or tea)	0.53	0.96	0.42	1.24	0.47	1.14
Sauces such as ketchup and mayo	0.36	0.69	0.22	0.26	0.32	0.97

Tea and Coffee	3.1	2.37	3.58	2.71	3.06	3.24
Cold beverages	0.98	1.66	1.04	1.01	0.59	1.79
Fruits	2.79	2.27	1.99	1.72	3.21	3.86
Vegetables	3.95	4.36	3.54	3.05	4.73	5.75

	Diagnosis group based on the HbA1c values					
	Normal (<6%)		**Pre-diabetic (6.0-6.5%)**		**Diabetic (>6.5%)**	
	M	**SD**	**M**	**SD**	**M**	**SD**
Red Meat	0.59	0.77	0.46	0.38	0.42	0.45
Chicken	0.81	0.89	0.54	0.4	0.56	0.6
Fried Chicken and Fish	0.23	0.38	0.13	0.1	0.2	0.36
Seafood	0.2	0.4	0.1	0.1	0.2	0.5
Processed Meat	0.15	0.3	0.04	0.09	0.08	0.2
Rice and Macaroni	0.85	0.87	0.9	0.74	0.97	1.06
White Bread	0.42	0.75	0.39	0.69	0.34	0.67
Brown Bread	0.41	0.6	0.49	0.84	0.62	0.79
Baked Items	0.39	0.49	0.35	0.73	0.39	1.06
Non-fried Potato	0.1	0.2	0.21	0.5	0.15	0.31
Fried Potato	0.16	0.21	0.13	0.23	0.12	0.23
Sugary Breakfast	0.24	0.49	0.2	0.63	0.14	0.34
Sandwiches	0.46	0.51	0.47	0.65	0.45	0.63
Full fat dairy items	1.44	1.18	1.6	1.26	1.4	1.43
Low and fat free dairy items	1	1.3	0.78	0.94	1.26	1.8
Margarine and Butter	0.19	0.37	0.17	0.26	0.21	0.56
Eggs	0.24	0.3	0.38	0.42	0.29	0.61
Confectionery and Other Sweets	0.68	0.72	0.61	0.98	0.83	1.5

Crisps	0.18	0.59	0.02	0.05	0.12	0.3
Nuts	0.16	0.27	0.14	0.26	0.1	0.21
Dried Fruits and Pickles	0.23	0.45	0.22	0.28	0.31	0.48
Soup	0.11	0.32	0.08	0.14	0.12	0.43
Sugar (Added to coffee or tea)	0.5	0.94	0.49	0.85	0.49	1.22
Sauces such as ketchup and mayo	0.32	0.67	0.13	0.3	0.38	1.02
Tea and Coffee	2.85	2.37	3.59	2.1	3.18	3.3
Cold beverages	0.84	1.54	0.72	1.2	0.67	1.9
Fruits	2.7	1.98	3.89	2.98	3.1	4
Vegetables	3.6	3.15	5.48	6.2	4.86	6.04

	Diagnosis group based on the HbA1c values excluding T2D					
	Non-DM (<6.0%)	**pre-DM (6.0-6.5%)**	**DM (>6.5%)**		**Non-DM (<6.0%)**	
	M	**SD**	**M**	**SD**	**M**	**SD**
Red Meat	0.62	0.83	0.58	0.3	0.35	0.5
Chicken	0.9	0.93	0.65	0.3	0.87	0.83
Fried Chicken and Fish	0.23	0.4	0.12	0.07	0.28	0.31
Seafood	0.3	0.4	0.1	0.1	0.2	0.3
Processed Meat	0.16	0.32	0.09	0.12	0.16	0.23
Rice and Macaroni	0.9	0.92	0.78	0.95	1.42	2.09
White Bread	0.46	0.8	0.6	0.91	0.72	1.2
Brown Bread	0.45	0.64	0.14	0.2	0.59	0.7
Baked Items	0.43	0.5	0.56	1.05	0.38	0.35
Non-fried Potato	0.11	0.21	0.14	0.18	0.07	0.15
Fried Potato	0.18	0.21	0.26	0.3	0.19	0.25
Sugary Breakfast	0.27	0.52	0.4	0.95	0.1	0.11

Sandwiches	0.48	0.54	0.84	0.84	0.48	0.51
Full fat dairy items	1.55	1.23	1.1	0.93	1.47	1.48
Low and fat free dairy items	0.93	1.32	0.77	0.9	1.79	2.63
Margarine and Butter	0.23	0.39	0.07	0.09	0.06	0.12
Eggs	0.28	0.31	0.49	0.45	0.36	0.33
Confectionery and Other Sweets	0.68	0.69	0.63	0.56	0.66	0.82
Crisps	0.18	0.63	0.05	0.07	0.16	0.28
Nuts	0.17	0.26	0.26	0.35	0.09	0.21
Dried Fruits and Pickles	0.24	0.46	0.27	0.36	0.14	0.18
Soup	0.13	0.35	0.02	0.03	0.37	1.24
Sugar (Added to coffee or tea)	0.58	1.01	0.21	0.38	0.42	1.24
Sauces such as ketchup and mayo	0.37	0.72	0.27	0.42	0.22	0.26
Tea and Coffee	3.03	2.42	3.65	1.99	3.58	2.71
Cold beverages	0.93	1.67	1.4	1.62	1.04	1.01
Fruits	2.63	2.02	3.99	3.62	1.99	1.72
Vegetables	3.58	3.26	6.72	9.2	3.54	3.05

	BMI Groups							
	Underweight (<18.5)		**Normal (18.5-24.9)**		**Overweight (25-29.9)**		**Obese (≥30)**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Red Meat	0.43	.	0.45	0.5	0.54	0.67	0.41	0.47
Chicken	0.43	.	0.79	1.13	0.53	0.44	0.69	0.64
Fried Chicken and Fish	0	.	0.23	0.44	0.18	0.25	0.23	0.41
Seafood	0.4	.	0.1	0.2	0.2	0.4	0.2	0.5

Processed Meat	0	.	0.11	0.19	0.08	0.15	0.11	0.28
Rice and Macaroni	0.43	.	1.07	0.91	0.81	0.95	1	1.06
White Bread	0	.	0.46	0.87	0.37	0.73	0.33	0.53
Brown Bread	1	.	0.52	0.71	0.6	0.95	0.54	0.61
Baked Items	0	.	0.29	0.41	0.46	1.25	0.37	0.58
Non-fried Potato	0.14	.	0.12	0.23	0.16	0.31	0.13	0.31
Fried Potato	0	.	0.13	0.18	0.09	0.19	0.16	0.25
Sugary Breakfast	0.05	.	0.17	0.31	0.16	0.36	0.17	0.46
Sandwiches	0	.	0.45	0.47	0.39	0.42	0.53	0.75
Full fat dairy items	0.43	.	1.61	1.53	1.35	1.37	1.51	1.34
Low and fat free dairy items	4	.	1.7	2.56	0.92	1.01	1.22	1.79
Margarine and Butter	0.14	.	0.18	0.32	0.15	0.3	0.22	0.64
Eggs	0.79	.	0.22	0.32	0.21	0.28	0.32	0.66
Confectionery and Other Sweets	0.1	.	0.46	0.68	0.72	1.26	0.86	1.36
Crisps	0	.	0.08	0.14	0.13	0.5	0.14	0.34
Nuts	0	.	0.06	0.1	0.12	0.22	0.14	0.25
Dried Fruits and Pickles	0	.	0.21	0.28	0.25	0.35	0.38	0.62

Soup	0	.	0.03	0.05	0.15	0.54	0.11	0.22
Sugar (Added to coffee or tea)	0.05	.	0.22	0.35	0.62	1.5	0.48	0.79
Sauces such as ketchup and mayo	0	.	0.24	0.39	0.27	0.54	0.43	1.17
Tea and Coffee	1.84	.	2.45	2.6	2.96	2.59	3.48	3.41
Cold beverages	0.1	.	0.98	1.67	0.77	2.3	0.73	1.08
Fruits	4.2	.	2.31	2	2.7	2	3.56	4.57
Vegetables	5.2	.	4.02	3.19	3.92	3.54	4.95	6.85

	An estimate of household income (SAR)									
	< 5000		**5000 – 10,000**		**10,000 – 15,000**		**15,000 – 20,000**		**> 20,000**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Red Meat	0.37	0.46	0.49	0.52	0.63	0.51	0.58	0.91	0.4	0.37
Chicken	0.47	0.47	0.6	0.5	0.75	1.09	0.73	0.51	1.09	0.74
Fried Chicken and Fish	0.18	0.47	0.23	0.26	0.25	0.45	0.21	0.27	0.25	0.3
Seafood	0.2	0.6	0.2	0.5	0.2	0.3	0.2	0.3	0.5	0.8
Processed Meat	0.05	0.14	0.1	0.18	0.16	0.34	0.12	0.22	0.18	0.43
Rice and Macaroni	0.84	0.75	0.91	0.76	0.84	0.63	0.96	1.42	0.7	0.63
White Bread	0.29	0.57	0.3	0.48	0.59	0.96	0.44	0.88	0.15	0.25

Brown Bread	0.57	0.63	0.41	0.5	0.58	1.13	0.63	0.88	0.52	0.78
Baked Items	0.37	0.68	0.29	0.46	0.37	0.41	0.63	1.92	0.34	0.43
Non-fried Potato	0.2	0.44	0.15	0.28	0.13	0.21	0.08	0.13	0.08	0.14
Fried Potato	0.13	0.26	0.13	0.2	0.18	0.23	0.07	0.17	0.13	0.19
Sugary Breakfast	0.14	0.43	0.17	0.33	0.15	0.44	0.24	0.39	0.07	0.17
Sandwiches	0.38	0.59	0.55	0.55	0.48	0.48	0.44	0.41	0.52	0.32
Full fat dairy items	1.61	1.6	1.28	1.29	1.55	1.26	1.59	1.4	1.13	1.55
Low and fat free dairy items	1.18	1.37	1.15	1.3	1.38	2.08	1.24	2.41	1.05	0.87
Margarine and Butter	0.25	0.77	0.16	0.35	0.15	0.22	0.16	0.35	0.2	0.47
Eggs	0.32	0.82	0.25	0.42	0.3	0.35	0.27	0.33	0.28	0.43
Confectionery and Other Sweets	0.76	1.63	0.89	1.26	0.71	0.73	0.67	1.31	0.67	0.6
Crisps	0.08	0.19	0.16	0.38	0.12	0.25	0.21	0.81	0.06	0.13
Nuts	0.06	0.11	0.09	0.16	0.16	0.27	0.19	0.32	0.25	0.36
Dried Fruits and Pickles	0.3	0.42	0.3	0.52	0.24	0.32	0.23	0.36	0.36	0.6
Soup	0.08	0.18	0.05	0.12	0.06	0.12	0.3	0.88	0.29	0.46
Sugar (Added to coffee or tea)	0.64	1.64	0.37	0.61	0.42	0.84	0.64	1.24	0.73	0.98
Sauces such as ketchup and mayo	0.25	0.74	0.4	0.9	0.26	0.41	0.38	1.3	0.88	1.52

Tea and Coffee	2.67	2.69	3.27	3.69	3.46	2.66	2.66	2.27	3.01	2.02
Cold beverages	0.39	0.57	0.69	1.17	1.3	3.43	0.77	0.85	0.93	0.79
Fruits	3.05	2.58	2.78	2.19	2.39	1.97	3.06	2.57	2.47	2.42
Vegetables	5.38	8.48	4.23	3.12	3.64	2.37	4.24	5.46	4.54	3.4

	Level of education													
	Illiterate		**Literate with no school education**		**Primary school**		**Middle school**		**High school**		**Bachelor degree**		**Postgraduate degree**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Red Meat	0.24	0.25	0.58	0.4	0.36	0.48	0.58	0.62	0.51	0.52	0.52	0.68	0.63	0.54
Chicken	0.38	0.35	0.37	0.29	0.63	0.46	0.3	0.42	0.59	0.48	0.79	0.73	1.03	1.39
Fried Chicken and Fish	0.1	0.17	0.23	0.41	0.11	0.15	0.1	0.14	0.25	0.26	0.24	0.42	0.33	0.62
Seafood	0.1	0.1	0.2	0.4	0.1	0.2	0.2	0.3	0.2	0.5	0.3	0.6	0.3	0.4
Processed Meat	0.02	0.13	0.04	0.14	0.02	0.05	0.07	0.1	0.13	0.33	0.14	0.22	0.09	0.18
Rice and Macaroni	0.81	0.81	1.02	0.7	1.09	0.8	0.82	0.76	1	0.82	0.95	1.27	0.79	0.65
White Bread	0.17	0.35	0.38	0.41	0.47	0.9	0.15	0.33	0.32	0.41	0.52	0.92	0.19	0.3
Brown Bread	0.47	0.54	0.53	0.82	0.8	0.83	0.46	0.48	0.52	0.64	0.64	0.94	0.47	0.82
Baked Items	0.2	0.5	0.17	0.24	0.38	0.81	0.23	0.45	0.37	0.53	0.52	1.28	0.45	0.47

Non-fried Potato	0.1	0.21	0.24	0.62	0.2	0.33	0.25	0.38	0.1	0.2	0.15	0.33	0.11	0.16
Fried Potato	0.03	0.1	0.05	0.14	0.27	0.39	0.07	0.14	0.12	0.19	0.17	0.25	0.17	0.18
Sugary Breakfast	0.08	0.21	0.04	0.05	0.12	0.29	0.1	0.17	0.22	0.49	0.21	0.48	0.14	0.28
Sandwiches	0.24	0.36	0.54	0.59	0.47	0.45	0.43	0.46	0.48	0.53	0.57	0.75	0.36	0.42
Full fat dairy items	1.2	1.41	2.17	2.12	2.08	1.54	1.22	1.13	1.62	1.5	1.32	1.18	1.6	1.16
Low and fat free dairy items	1.54	1.93	0.61	0.74	1.14	1.48	1.22	1.61	1.31	2.19	1.06	1.42	0.88	1.13
Margarine and Butter	0.12	0.31	0.27	0.35	0.25	0.37	0.11	0.27	0.18	0.38	0.2	0.63	0.27	0.44
Eggs	0.13	0.2	0.26	0.36	0.24	0.33	0.3	0.36	0.26	0.44	0.33	0.7	0.38	0.39
Confectionery and Other Sweets	0.42	0.71	0.4	0.38	1.06	2.68	0.91	1.48	0.88	1.31	0.83	1.19	0.71	0.59
Crisps	0.02	0.07	0.04	0.14	0.1	0.27	0.13	0.27	0.16	0.41	0.13	0.24	0.34	1.09
Nuts	0.04	0.09	0.06	0.14	0.1	0.23	0.13	0.31	0.1	0.2	0.15	0.24	0.26	0.33
Dried Fruits and Pickles	0.23	0.47	0.3	0.47	0.65	0.81	0.19	0.27	0.32	0.53	0.28	0.4	0.27	0.43
Soup	0.05	0.1	0.07	0.14	0.15	0.28	0.05	0.06	0.06	0.14	0.14	0.52	0.31	0.62
Sugar (Added to coffee or tea)	0.25	0.57	0.78	1.19	0.75	1.16	0.33	0.39	0.3	0.48	0.6	1.47	0.83	1.25
Sauces such as ketchup and mayo	0.11	0.48	0.03	0.09	0.08	0.22	0.37	0.92	0.38	0.83	0.49	1.13	0.31	0.44

Tea and Coffee	2.98	3.83	2.21	1.98	3.35	2.21	2.13	1.53	2.98	2.93	3.47	3.02	2.88	1.64
Cold beverages	0.32	0.65	0.56	0.97	0.7	0.77	0.73	1.16	0.9	1.74	0.97	2.38	0.84	0.57
Fruits	2.76	2.34	3.94	2.24	3.58	1.81	2.67	1.87	2.98	2.73	3.14	4.71	2.58	1.9
Vegetables	3.03	2.39	4.62	2.16	5.71	2.9	4.91	4.51	3.93	2.68	5.21	7.66	4.1	3.78

	Smoking			
	No		**Yes**	
	M	**SD**	**M**	**SD**
Red Meat	0.4	0.53	0.66	0.53
Chicken	0.62	0.69	0.69	0.64
Fried Chicken and Fish	0.19	0.36	0.25	0.31
Seafood	0.2	0.4	0.3	0.5
Processed Meat	0.08	0.19	0.15	0.32
Rice and Macaroni	0.88	0.89	1.08	1.24
White Bread	0.37	0.69	0.34	0.62
Brown Bread	0.57	0.7	0.57	1
Baked Items	0.38	0.95	0.39	0.53
Non-fried Potato	0.14	0.32	0.12	0.18
Fried Potato	0.12	0.21	0.14	0.22
Sugary Breakfast	0.14	0.33	0.21	0.53
Sandwiches	0.39	0.58	0.64	0.6
Full fat dairy items	1.48	1.43	1.4	1.2
Low and fat-free dairy items	1.1	1.61	1.35	1.87
Margarine and Butter	0.2	0.51	0.13	0.21

Eggs	0.28	0.55	0.23	0.34
Confectionery and Other Sweets	0.77	1.36	0.68	0.72
Crisps	0.13	0.43	0.1	0.23
Nuts	0.11	0.21	0.11	0.23
Dried Fruits and Pickles	0.25	0.38	0.34	0.52
Soup	0.1	0.26	0.16	0.64
Sugar (Added to coffee or tea)	0.5	1.14	0.45	0.9
Sauces such as ketchup and mayo	0.29	0.85	0.38	0.69
Tea and Coffee	3.08	3.04	3.23	2.84
Cold beverages	0.49	0.65	1.58	3.22
Fruits	3.21	3.67	2.44	2.32
Vegetables	4.57	5.53	3.98	4.06

	Exercise Regularly			
	No		**Yes**	
	M	**SD**	**M**	**SD**
Red Meat	0.47	0.5	0.45	0.63
Chicken	0.67	0.79	0.58	0.46
Fried Chicken and Fish	0.22	0.41	0.18	0.23
Seafood	0.2	0.5	0.2	0.3
Processed Meat	0.11	0.25	0.08	0.16
Rice and Macaroni	0.92	0.93	0.94	1.08
White Bread	0.33	0.63	0.4	0.73
Brown Bread	0.53	0.68	0.62	0.9
Baked Items	0.4	1.04	0.36	0.54
Non-fried Potato	0.16	0.34	0.1	0.18
Fried Potato	0.13	0.23	0.11	0.19

Sugary Breakfast	0.15	0.41	0.19	0.39
Sandwiches	0.47	0.66	0.43	0.48
Full fat dairy items	1.48	1.37	1.42	1.4
Low and fat-free dairy items	1.15	1.53	1.26	1.95
Margarine and Butter	0.21	0.56	0.15	0.29
Eggs	0.29	0.61	0.24	0.3
Confectionery and Other Sweets	0.8	1.32	0.66	1.1
Crisps	0.14	0.44	0.09	0.3
Nuts	0.12	0.23	0.11	0.22
Dried Fruits and Pickles	0.29	0.54	0.3	0.38
Soup	0.1	0.21	0.14	0.54
Sugar (Added to coffee or tea)	0.53	1.19	0.42	0.9
Sauces such as ketchup and mayo	0.35	1	0.29	0.56
Tea and Coffee	3.11	2.66	3.09	3.43
Cold beverages	0.68	1.22	0.91	2.31
Fruits	3.14	3.85	2.84	2.54
Vegetables	4.55	5.95	4.18	3.74

	Family history of T2D			
	No		**Yes**	
	M	**SD**	**M**	**SD**
Red Meat	0.52	0.54	0.45	0.56
Chicken	0.57	0.56	0.64	0.7
Fried Chicken and Fish	0.18	0.22	0.2	0.31
Seafood	0.2	0.3	0.2	0.4
Processed Meat	0.08	0.13	0.1	0.25
Rice and Macaroni	1.01	1.18	0.91	0.94

White Bread	0.3	0.68	0.37	0.67
Brown Bread	0.46	0.59	0.6	0.82
Baked Items	0.24	0.43	0.42	0.97
Non-fried Potato	0.11	0.32	0.13	0.25
Fried Potato	0.09	0.15	0.13	0.23
Sugary Breakfast	0.08	0.18	0.18	0.39
Sandwiches	0.47	0.73	0.44	0.5
Full fat dairy items	1.34	1.21	1.5	1.43
Low and fat-free dairy items	1.22	1.71	1.2	1.72
Margarine and Butter	0.21	0.36	0.15	0.32
Eggs	0.18	0.26	0.26	0.36
Confectionery and Other Sweets	0.58	0.86	0.8	1.34
Crisps	0.06	0.13	0.14	0.44
Nuts	0.09	0.18	0.13	0.24
Dried Fruits and Pickles	0.28	0.47	0.29	0.47
Soup	0.09	0.18	0.12	0.42
Sugar (Added to coffee or tea)	0.51	1.63	0.47	0.87
Sauces such as ketchup and mayo	0.13	0.24	0.37	0.92
Tea and Coffee	2.93	2.44	3.11	3.06
Cold beverages	0.54	0.74	0.83	1.93
Fruits	3.67	5.61	2.79	2.28
Vegetables	3.73	2.61	4.28	3.75

Appendix 6: Ethical approval for the analysis of the secondarily acquired SHIS data

The University Of Sheffield.

Approved: 07/06/2017

Fahad Almutairi
Registration number: 150253622
School of Health and Related Research
Programme: Public health PhD

Dear Fahad

PROJECT TITLE: Secondary data analysis to examine the relation between diet and type 2 diabetes in Saudi Arabia
APPLICATION: Reference Number 014594

On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 07/06/2017 the above-named project was **approved** on ethics grounds, on the basis that you will adhere to the following documentation that you submitted for ethics review:

- University research ethics application form 014594 (form submission date: 24/05/2017); (expected project end date: 30/06/2017).

If during the course of the project you need to deviate significantly from the above-approved documentation please inform me since written approval will be required.

Your responsibilities in delivering this research project are set out at the end of this letter.

Yours sincerely

Jennifer Burr
Ethics Administrator
School of Health and Related Research

Please note the following responsibilities of the researcher in delivering the research project:

- The project must abide by the University's Research Ethics Policy: https://www.sheffield.ac.uk/rs/ethicsandintegrity/ethicspolicy/approval-procedure
- The project must abide by the University's Good Research & Innovation Practices Policy: https://www.sheffield.ac.uk/polopoly_fs/1.671066!/file/GRIPPolicy.pdf
- The researcher must inform their supervisor (in the case of a student) or Ethics Administrator (in the case of a member of staff) of any significant changes to the project or the approved documentation.
- The researcher must comply with the requirements of the law and relevant guidelines relating to security and confidentiality of personal data.
- The researcher is responsible for effectively managing the data collected both during and after the end of the project in line with best practice, and any relevant legislative, regulatory or contractual requirements.

Appendix 7: Ethical approval for data collection in Saudi Arabia

وزارة الصحة
Ministry of Health

Date: ١٠/٩/١٤٣٨
IRB-81

Institutional Review Board, General Directorate of Health Affairs in Madinah

To **Fahad Almutairi**

This is to certify that Institutional Review Board (IRB), General Directorate of Health Affairs in Madinah has reviewed all the submitted updated and amended Documents from the ethical pointview and has approved your study titled: ***" Association between dietary patterns and risk for Type 2 diabetes in Saudi Arabia".***

The committee is fully compliant with the conditions and principles of good clinical practice. The committee is constituted in accordance with the WHO and ICH-GCP guidelines and works according to written Standard operating Procedures.

Below are the list of IRB members that reviewed and approved the above mentioned documents, Kindly to know that only those IRB members who are independent of the investigator and the sponsor vote/ provide opinion on Trial related matter:

1. Dr. Osamah Alhayani — Head of IRB Committee
2. Dr. Ahmad Al-Fraidi — IRB Coordinator

The IRB recommended granting permission of approval to conduct the project along the following terms:

1. If there are any further amendments, they must be approved prior to implementation unless they are intended to reduce risk.
2. Monitoring: the project may be subject to an audit or any other form of monitoring by the REC.
3. All unanticipated or serious adverse events must be reported to the REC within 5 days or according to the protocol
4. Inform the IRB prior to making prospective changes to the study procedure
5. Upon the study completion, The PI is expected to submit a final report at the end of the study

Please note that this approval is valid for one year commencing from the date of this letter.

Head OF IRB Committee

Dr. Osamah Alhayani

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