UNIVERSITI PUTRA MALAYSIA

EFFECTS OF MEALS DIFFERING IN GLYCEMIC INDEX ON POSTPRANDIAL GLUCOSE AND INSULIN LEVELS IN INDIVIDUALS WITH AND WITHOUT TYPE 2 DIABETES MELLITUS

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By

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January 2021

Chair : Barakatun Nisak binti Mohd Yusof, PhD
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Postprandial hyperglycemia increases the risk of cardiovascular diseases not only in individuals with type 2 diabetes mellitus (T2DM) and without T2DM. A low glycemic index (GI) diet improved postprandial glycemia, but the results are still inconsistent. Therefore, this study determined the effects of differing meal GI on postprandial glucose and insulin levels in individuals with and without T2DM.

This was a randomized crossover study, with a one-week washout period conducted at the endocrine laboratory, Hospital Canselor Tuanku Muhriz (HCTM). A total of 40 individuals participated in the study (T2DM; n=20; without T2DM; n=20). Baseline assessments included anthropometric assessments, biochemical profile, dietary intake, and physical activity level. The test meals designed to be in iso-caloric but different in meal GI. T2DM subjects were asked to attend both test meals with one-week washout period, and without T2DM attended one study visit for a high GI meal, represent the typical meal for the general population. The testing procedures based on the meal-challenge test (MCT) techniques for glucose and insulin responses. Fasting blood was obtained at 0 minutes, followed by eating the test meals for 20 minutes. Subsequent blood samples were obtained at 30, 60, 120, 180 and 240 minutes.

At baseline, T2DM subjects had higher body mass index (BMI), waist circumference, blood pressure, glycemic profiles, lower total and LDL-cholesterol, higher dietary fat and fibre intake compared to without T2DM. After consuming the high GI meal, the postprandial glucose response in T2DM was significantly higher at all time points than without T2DM ($p<0.001$). T2DM had a significantly higher glucose incremental area under the curve (iAUC) at 240 minutes than without T2DM ($p<0.001$). T2DM had significantly lower insulin level at 30 minutes ($p<0.05$) and higher insulin levels at 180

and 240 minutes ($p<0.001$) than without T2DM. There were no significant differences in insulin iAUC at 240 minutes between T2DM and without T2DM. In T2DM, there were no significant difference between the glucose profiles over time between the two meals. However, low GI meal produced higher insulin responses at 30 minutes and lower at 180 and 240 minutes than after high GI meal ($p<0.05$) with no difference in iAUC.

In conclusion, T2DM produced higher glucose and insulin response after consuming high GI meals. Meals differing in GI value produced different effects on insulin but not glucose levels. The low GI meal produced lower insulin responses suggesting reduced insulin requirements following low GI meal consumption.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KESAN MAKANAN DENGAN NILAI INDEKS GLISEMIK BERBEZA TERHADAP PARAS GLUKOS DAN INSULIN *POSTPRANDIAL* DALAM KALANGAN INDIVIDU DENGAN DAN TANPA DIABETES MELLITUS JENIS DUA

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Peningkatan gula darah *postprandial* meningkatkan risiko penyakit kardiovaskular bukan sahaja dalam individu dengan diabetes mellitus jenis dua (T2DM) tetapi juga individu tanpa T2DM (tanpa T2DM). Diet rendah indeks glisemik (GI) menurunkan gula darah *postprandial* tetapi hasil kajian masih tidak konsisen. Oleh itu, kajian ini menentukan kesan makanan dengan nilai GI berbeza terhadap paras glukos dan insulin *postprandial* dalam kalangan T2DM dan tanpa T2DM.

Kajian ini berbentuk pindah silang, dengan tempoh *washout* selama seminggu, dijalankan di makmal endokrin, Hospital Canselor Tuanku Muhriz (HCTM). Seramai 40 individu menyertai kajian (T2DM; n=20, tanpa T2DM; n=20). Penilaian asas dilakukan termasuk penilaian antropometri, profil biokimia, pengambilan makanan dan tahap aktiviti fizikal. Makanan kajian direka secara iso-kalori dengan nilai GI berbeza. T2DM diminta untuk menyertai dua kali kajian dalam tempoh *washout* selama seminggu, dan tanpa T2DM menyertai sekali kajian makanan tinggi GI sahaja. Makanan tinggi GI mewakili makanan yang biasa diambil oleh populasi Malaysia. Prosedur kajian menggunakan teknik *meal-challenge test* (MCT) untuk respons glukos dan insulin. Darah berpuasa diambil pada 0 minit, diikuti dengan pengambilan makanan kajian dalam masa 20 minit. Kemudian, sampel darah diambil pada 30, 60, 120, 180 dan 240 minit.

Pada data asas, T2DM mempunyai indeks jisim tubuh, ukurlilit pinggang, tekanan darah, profil glisemik, pengambilan lemak dan serat yang lebih tinggi, dan kolesterol total dan LDL yang lebih rendah berbanding dengan tanpa T2DM. Setelah mengambil makanan tinggi GI, paras glukos *postprandial* dalam T2DM lebih tinggi secara

signifikan pada setiap titik waktu berbanding dengan tanpa T2DM ($p<0.001$). T2DM menunjukkan iAUC glukos yang lebih tinggi pada 240 minit daripada tanpa T2DM ($p<0.001$). T2DM mempunyai paras insulin yang lebih rendah pada 30 minit ($p<0.05$) dan tinggi pada 180 dan 240 minit ($p<0.001$) daripada tanpa T2DM. iAUC insulin tidak berbeza pada 240 minit antara T2DM dan tanpa T2DM. Paras glukos *postprandial* tidak berbeza secara signifikan antara makanan tinggi dan rendah GI. Walau bagaimanapun, makanan rendah GI menunjukkan paras insulin yang lebih tinggi pada 30 minit dan rendah pada 180 dan 240 minit secara signifikan berbanding dengan makanan tinggi GI ($p<0.05$), dan tiada perbezaan signifikan pada iAUC insulin.

Kesimpulannya, T2DM menunjukkan respons glukos dan insulin yang lebih tinggi selepas mengambil makanan tinggi GI. Makanan dengan nilai GI berbeza memberi kesan pada paras insulin tetapi bukan pada glukos. Makanan rendah GI menghasilkan respons insulin yang lebih rendah menggambarkan penurunan keperluan insulin.

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LIST OF ABBREVIATIONS

ADA	American Diabetes Association
AGEs	Advanced Glycation-end Products
AUC	Area under curve
BMI	Body Mass Index
CONSORT	Consolidated Standards of Reporting Trials
CPG	Clinical Practice Guidelines
CVD	Cardiovascular Diseases
DECODA	Diabetes Epidemiology: Collaborative Analysis of Diagnostic Criteria in Asia
DECODE	Diabetes Epidemiology: Collaborative Analysis of Diagnostic Criteria in Europe
DHQ	Dietary History Questionnaire
DSF	Diabetes Specific Formula
eGFR	Estimated Glomerular Filtration Rate
EI:BMR	Ratio of Energy Intake: Basal Metabolic Rate
FFA	Free Fatty Acids
GDM	Gestational Diabetes Mellitus
GI	Glycemic Index
GIP	Gastric Inhibitory Peptide-1
GL	Glycemic Load
GLP-1	Glucagon-like Peptide-1
HbA1c	Glycosylated Haemoglobin
HCTM	Hospital Canselor Tuanku Muhriz
HDL-cholesterol	High-density Lipoprotein cholesterol
HOMA-IR	Homeostasis Model Assessment of Insulin Resistance

iAUC	Incremental Area Under Curve
IDF	International Diabetes Federation
IGT	Impaired Glucose Tolerance
IPAQ	International Physical Activity Questionnaire
KPPC	Klinik Primer Pusat Perubatan UKM Cheras
LDL-cholesterol	Low-density Lipoprotein cholesterol
MANS	Malaysian Adult Nutrition Surveys
MCT	Meal-Challenge Test
METs	Metabolic Equivalent of Task
MNT	Medical Nutrition Therapy
MUFA	Monounsaturated Fatty Acids
NCD	Non-Communicable Diseases
NHMS	National Health and Morbidity Survey
NMR	Nuclear Magnetic Resonance
Non-T2DM	Individuals without Type 2 Diabetes Mellitus
OAD	Oral Anti-Diabetic Drug
OGTT	Oral Glucose Tolerance Test
PUFA	Polyunsaturated Fatty Acids
QUICKI	Quantitative Insulin Sensitivity Check Index
RAAS	Renin-Angiotensin Aldosterone System
RCT	Randomized Cross-over Trial
RNI	Recommended Nutrient Intake
SD	Standard Deviation
SFA	Saturated Fatty Acids
T1DM	Type 1 Diabetes Mellitus

T2DM	Individuals with Type 2 Diabetes Mellitus
UPM	Universiti Putra Malaysia
WC	Waist Circumference
WHO	World Health Organization
WHR	Waist:Hip Ratio

CHAPTER 1

INTRODUCTION

1.1 Background

Type 2 Diabetes Mellitus is a major global health concern with the highly prevalent diseases in the 21st century (International Diabetes Federation, 2019). It is one of the major disease burdens worldwide and significantly related to increased morbidity and mortality (World Health Organization (WHO), 2016). Approximately 79% of individuals with T2DM (T2DM) are living in low- and middle-income countries. In Malaysians aged over 20, the prevalence of T2DM is the highest (16.8%) compared to neighbouring countries such as Singapore (14.2%) and Thailand (8.3%) (International Diabetes Federation, 2019).

Among those with T2DM, poor glycemic control continues to be unabated. In Malaysia, the overall HbA1c level was 8.5% in 2013, and it did not differ significantly in the past five years (Mohamed et al., 2016). The proportion of T2DM achieving target HbA1c of <6.5% is low, between 12 and 20% (Firouzi et al., 2015; Mohamed et al., 2016). Also, the majority of the T2DM had excessed postmeal glucose known as postprandial hyperglycemia. They had a postprandial glucose levels above 7.8mmol/L two hours after a meal even when they had optimal glycemic control (Mohamed et al., 2016; van Dijk et al., 2011). In Malaysia, postprandial glycemic control is not optimal, and T2DM commonly experiences persistent postprandial hyperglycemia (12.7 mmol/L), which is the highest in South East Asia (Mohamed, 2008). Furthermore, 40% of T2DM in Malaysia did not achieve optimal postprandial glycemia (<10mmol/L) (Abougalambou et al., 2017).

Despite achieving optimal overall glycemic control and fasting glycemia, the optimal achievement of postprandial glycemia is equally essential in the management of T2DM. Elevated postprandial glycemia and insulin level have also been observed in non-T2DM particularly those having a family history of diabetes (Henninger et al., 2017). When 926 non-T2DM who had a family history of diabetes with first-degree relatives with T2DM participated in the oral-glucose tolerance test (OGTT), 40% of them had a level of >8.6mmol/L at 1-hour (Bianchi et al., 2013). These individuals had impaired β-cell function, less insulin-sensitive, more insulin-resistant, and had an unsatisfactory cardiovascular risk profile compared to individuals who had 1-hour postprandial glucose of <8.6mmol/L (Bianchi et al., 2013). In a prospective cohort study of Chinese non-T2DM (n=16,590), it was found that high postprandial glycemia is associated with the risk of cardiovascular disease (CVD) and all-cause death, even after the adjustment for cardiovascular risk factors (Chien et al., 2009).

The focus of management of postprandial glycemia is even more pertinent in the Malaysian context. When comparing non-T2DM from different ethnic origins, Asians

from the South East region had the highest postprandial glycemic and reduced insulin sensitivity than European and Arabic Caucasians, Chinese and Asian Indians (Dickinson et al., 2002). Among Asians T2DM, despite having normal fasting glycemic level, the excessive rise in postprandial glycemic levels is commonly observed due to relative insulin insensitivity (Venn et al., 2010). The phenomenon highlights the importance of targeting postprandial glycemia in the management of T2DM. This is critical especially since humans spend much time in the postprandial state rather than at the fasting state.

Nutrition intake influences postprandial glycemia in T2DM. The postprandial glycemia, as assessed by iAUC was lowered by 21% by modifying the amount and type of carbohydrate (Wolever et al., 2013). Furthermore, the all-day glucose iAUC was reduced by 86% by reducing the amount of carbohydrates and choosing carbohydrates that were low in GI and high in fibre (Francois et al., 2018).

The type of carbohydrate known as a GI concept is used to classify dietary carbohydrates based on their effect on postprandial glycemia (Augustin et al., 2015). The GI values are divided into three categories (i) low GI: <55, (ii) intermediate GI: 56-69 and (iii) high GI: >70. American Diabetes Association (ADA) and the International Diabetes Federation (IDF) recommend a low GI diet in T2DM as it has shown the benefits of the overall glycemic control assessed using HbA1c. A high GI meal (GI=70) increased postprandial glycemia by 39% and insulinemia response by 26% compared to a low GI meal (GI=37) in T2DM (Barakatun Nisak et al., 2009). Also, a high GI meal that is low in fibre produced significantly higher glucose and insulin iAUC than a low GI meal that is high in fibre (Silva et al., 2015).

There is a considerable amount of studies attempted to assess the efficacy of meals differing in GI on the postprandial metabolic parameters including glycemia, insulin, glucagon-like peptide-1 (GLP-1). Free fatty acids (FFA), and triglyceride. A study among the US population with T2DM found lowered postprandial glycemia and higher GLP-1 secretion, but no significant effect in the insulin, FFA, and triglycerides level after low GI meal consumption (Mottalib et al., 2016). However, the postprandial glycemia and insulin were significantly lowered when Indian T2DM consumed low GI meal as compared to the isocaloric meal (Gulati et al., 2015).

A similar benefit on postprandial glycemia and insulin was observed in Caucasians T2DM after consuming meals differing in GI for 4 weeks (Kabir et al., 2002). In Malaysia, an iso-caloric meal low in GI demonstrated the benefit of lowering postprandial glycemia and insulin response in T2DM (Barakatun Nisak, Ruzita, et al., 2009). When this study was lengthened to 3 months, T2DM consumed low GI meal shown significantly lowered postprandial glycemia at 0, 60, 150, and 180 minutes. However, they were challenged with high GI meal, there were no significant differences in the postprandial insulin response (Barakatun Nisak et al., 2009). In sum, previous studies' findings when using meals differing in GI on the postprandial metabolic parameters were inconsistent.

When conducting a study for meals differing in GI, several confounding factors need to be controlled as it could influence the postprandial glycemia and insulin responses. Primarily, in the diet context, the composition and macronutrient distribution of the meal would affect postprandial glycemia (Jakubowicz et al., 2017). Consumption of huge portions of foods, nuts and legumes, alcohol intake the day before the study would affect the postprandial glycemia (Barakatun Nisak, Ruzita, et al., 2009; Silva et al., 2015; Voss et al., 2008). An overnight fast of at least 6 hours is required before the test meals, as reported by (Mottalib et al., 2016). Next, strenuous physical activity was not allowed before and during the study to avoid extra physical stress (Gulati et al., 2015).

The consistency of lifestyle patterns in T2DM between the test meals must be maintained throughout the study (Barakatun Nisak, Ruzita, et al., 2009; Kabir et al., 2002). This ensures that there is no carry-over effect of the previous test meals or lifestyle modifications onto the clinical effects (Mottalib et al., 2016) . The intra-variability within the subject such as body weight, dietary intake, and physical activity level between each test meal has to be controlled (Barakatun Nisak, Ruzita, et al., 2009; Mottalib et al., 2016). Besides, the medications need to be reviewed in every visit to ensure there are no changes in the glucose-lowering agents (Devitt et al., 2012).

1.2 Problem Statement

A high GI meal produces more significant fluctuations in blood glucose levels and worsens glycemic control in T2DM (Brand-Miller et al., 2003; Kaur et al., 2015). About 42% of Malaysian individuals had moderate physical activity levels (Chan et al., 2017). However, the prevalence of physical inactivity is high in Malaysia (K. L. Tan, 2019; Tee & Yap, 2017). Age, sex, marital status, working hours, and individuals' readiness were associated with physical inactivity in non-T2DM (K. L. Tan, 2019). Besides, ethnicity, educational level, and occupation were also predictors of low physical activity level (Lian et al., 2016). In short, there is a need to compare the socio-demographic characteristics and nutritional status profiles between individuals with and without T2DM.

The glycemic control of Malaysian T2DM is not optimal and did not meet the target treatment goal (Mohamed et al., 2016). Poor glycemic control contributed to the development of various diabetes-related complications especially CVD, thereby leading to a higher morbidity and mortality rate (Nakagami, 2004; Preis et al., 2009; Rawshani et al., 2018). The possible factors of high postprandial glycemia observed in Malaysian T2DM are male with longer duration of T2DM, and poor adherence to diet and exercise (Abougalambou et al., 2017; Mafauzy et al., 2011). Extensive measures warrant implementing optimal glycemic control (P. C. Yu et al., 2010).

The impact of a low GI diet on HbA1c level has been well established (Barakatun Nisak, Talib, et al., 2009; Ojo et al., 2018; Zafar et al., 2019). In Malaysia, there were five studies conducted using a low GI diet. When a low GI diet was compared to the usual diet for 12 weeks, there was a significant 0.7% reduction in the HbA1c level

(Barakatun Nisak et al., 2010). The impact of a 4-week low GI diet in women with gestational diabetes mellitus (GDM) was evaluated (Farhanah et al., 2017). Besides, the effect of a 6-month low GI diet was studied among women with a previous history of GDM (Shyam et al., 2013). In both of these studies, the postprandial glucose was significantly reduced in the low GI diet than conventional nutrition therapy (Farhanah et al., 2017; Shyam et al., 2013). Nonetheless, the comparison between high and low GI meal in postprandial metabolic parameters in the T2DM population was limited.

The postprandial state reveals multiple aspects of metabolic health that would not be apparent from solely studying the HbA1c level. The evidence among T2DM was well documented in other countries such as India (Gulati et al., 2015), the USA (Devitt et al., 2012; Mottalib et al., 2016; Voss et al., 2008), and Brazil (Cocate et al., 2011; Silva et al., 2015). These studies have shown beneficial effects of a low GI meal in lowering the postprandial glucose levels, but the postprandial response of other parameters such as insulin levels have been inconsistent (Cocate et al., 2011; Devitt et al., 2012; Gulati et al., 2015; Mottalib et al., 2016). In Malaysia, one study investigated the acute effect of low GI meal on the postprandial glucose and insulin response among T2DM (Barakatun Nisak, Ruzita, et al., 2009). Nonetheless, the study did not compare the postprandial effect of meals between individuals with and without T2DM. It is essential to understand the postprandial response of meals because humans spend much time in the postprandial state than at the fasting state. Non-T2DM would also have increased risk of CVD if they have an excessive rise in the postprandial level. The Diabetes Epidemiology: Collaborative analysis of Diagnostic criteria in Europe (the DECODE) and Asia (the DECODA) studies reported that postprandial hyperglycemia is strongly related to oxidative stress, leading to the mortality associated with CVD not only in T2DM but also in those without T2DM (Dickinson et al., 2002; Nakagami et al., 2003).

In non-T2DM, available studies mainly conducted to determine the GI value of food items or compare the effect of high GI meals and moderate/low GI meals. In Brazil, when young healthy men (n=15) consumed a high GI meal (GI=79), significantly higher postprandial glycemia and insulin response were reported (Cocate et al., 2011). An acute study had shown a 9% significant reduction in postprandial glycemia and a 43% reduction in postprandial insulin when non-T2DM consumed a low GI meal (GI=43) compared to a high GI meal (GI=70) (Gaesser et al., 2019). When 38 overweight non-T2DM consumed a low GI meal for 5-week, there was an 8% reduction in the postprandial glycemia but no significant difference in the insulin response (Nazare et al., 2010). The Asian study in Singapore found that a high GI meal increased the glycemic response significantly even in the subsequent meals of the day (Kaur et al., 2015). A comparison of high GI meal on postprandial metabolic parameters between individuals with and without T2DM is lacking.

Generally, a high GI meal produced a higher glycemic response while a low GI meal produced a lower glycemic response (Augustin et al., 2015). A high GI meal is considered sufficient to compare the effect of postprandial glycemic and insulin responses between T2DM and non-T2DM. This is because the beneficial effect of high GI meal would also reflect in a low GI meal. Next, the high GI meal was a standard meal usually consumed by all individuals as part of their breakfast meal (Barakatun Nisak, Abd. Talib, et al., 2009; Kaur et al., 2015). This standard healthy meal that is

high in GI would reflect the actual scenario. The GI values of the high GI meals were designed to match the baseline GI (64 and 63) of the Malaysian population as reported previously among studies conducted in T2DM (Barakatun Nisak et al., 2010; Barakatun Nisak, Talib, et al., 2009) respectively. The main source of carbohydrates consumed by the Malaysian population is rice (Norimah et al., 2008).

Nevertheless, rice gives unpredictable postprandial responses due to factors such as amylose to amylopectin ratio, the combination of protein and fat, and the duration of cooking (Boers et al., 2015). A previous study conducted by (Barakatun Nisak, Ruzita, et al., 2009) used wholemeal bread and banana were as high GI meal; while wholegrain bread and apple were used as low GI meal. However, the postprandial effect when comparing high GI meal (white bread and skim milk) to a low GI meal consisted of wholegrain bread and diabetes-specific formula (DSF) in Malaysian T2DM remains to be elucidated.

DSF was added to lower the GI of the meal and extend further understanding of the effect on postprandial glucose and insulin levels in T2DM. DSF is nutritionally balanced between carbohydrates, protein-blend and fats, designed to facilitate the management of glycemic response in T2DM (Lansink et al., 2011; Mottalib et al., 2016). Previously published studies have demonstrated the benefit of DSF alone in improving postprandial glycemia in T2DM (Gulati et al., 2015; Mottalib et al., 2016), yet the impact of the combination of DSF with low GI meal has not been investigated. Therefore, this study determined the effects of meals differing in GI on postprandial glucose and insulin levels in individuals with and without T2DM.

1.3 Research Questions

1. Is there any difference between the sociodemographic characteristics, health status and lifestyle practices, and nutritional status between individuals with and without T2DM?
2. Is there any difference in the postprandial glucose and insulin levels between individuals with and without T2DM after consuming high GI meal?
3. Is there any difference in the postprandial glucose and insulin levels between high GI and low GI meals in individuals with T2DM?

1.4 General Objective

To determine the effect of meals differing in GI on postprandial glucose and insulin levels in individuals with and without T2DM.

1.5 Specific Objective

1. To determine and compare the sociodemographic characteristics, health status and lifestyle practices, and nutritional status (anthropometry, biochemical profile, dietary intake, and physical activity level) in individuals with and without T2DM at baseline.
2. To determine and compare the effects of high GI meal on postprandial glucose and insulin levels between individuals with and without T2DM.
3. To determine and compare the effects between high and low GI meals on postprandial glucose and insulin levels in individuals with T2DM.
4. To determine intra-variability within individuals with T2DM including weight, dietary intake, and physical activity level between high and low GI meals as quality control.

1.6 Null Hypothesis

1. There is no significant difference in sociodemographic characteristics, health status and lifestyle practices, and significant differences in the nutritional status (anthropometry, biochemical profile, dietary intake, and physical activity level) in individuals with and without T2DM at baseline.
2. There is a significant difference in postprandial glycemic and insulin levels between individuals with and without T2DM after consuming high GI meal.
3. There is a significant difference in the postprandial glycemic and insulin levels between high and low GI meals in individuals with T2DM.
4. There is no significant difference in intra-variability within the subject including weight, dietary intake, and physical activity level between high and low GI meals in individuals with T2DM.

1.7 Study Significance

The findings of this study provide new insight into the metabolic effects of high and low GI meals, particularly in T2DM, and further understand the mechanism in non-T2DM.

Although T2DM would produce a higher postprandial impact than non-T2DM after consuming a high GI meal, a local study looking into the postprandial glycemic and insulin response after a standard high GI meal ingestion has not yet been investigated. Available local data mainly focused on determining the GI value of specific food items in non-T2DM rather than on the postprandial response of meals. Thus, this study provides new insights into the postprandial effect of standard high GI meal consumption in Malaysia individuals with and without T2DM.

Furthermore, baseline data of postprandial glucose and insulin levels in T2DM in response to meals differing in GI can be established through this study. The favourable

effect in the postprandial glycemic fluctuations by incorporating a low GI meal would suggest a possibility preventing deterioration in pancreatic β-cell function (Blaak et al., 2012; Silva et al., 2015). Besides, the benefit would be extended further to reduce the CVD risk factors that are the primary cause of death in T2DM (Pinés Corrales et al., 2020).

The data obtained would support the Clinical Practice Guidelines (CPG) and clinical practices by dietitians and healthcare professionals. The implications of this study are to create an appropriate meal plan for T2DM with confirmed benefits to glucose and insulin to be used in the clinic. The incorporation of low GI meal and its evidence in postprandial glycemic management can be used to convince T2DM.

The awareness of the Malaysian society about the concept of GI is still in its infancy. The finding would generate insights into the food industry to innovate foods with low GI that is friendly to the postprandial response. The advantage could be extrapolated to public health, to promote GI labelling in more food items for individuals living with T2DM to make reliable and healthier food choices. In Canada, the concept of GI labelling was well accepted among consumers as it helped to facilitate healthier carbohydrate choices (Marinangeli et al., 2019).

1.8 Conceptual framework

The conceptual framework of this study is presented in Figure ***1.***. It is hypothesized that meals differing in GI provided to individuals with and without T2DM have an effect on the postprandial glucose and insulin levels. T2DM may have altered postprandial metabolic response compared to non-T2DM when they consumed a high GI meal. A low GI meal may improve the postprandial metabolic response (i.e. glucose and insulin) compared to a standard high GI meal in T2DM (Barakatun Nisak, Ruzita, et al., 2009; Gulati et al., 2015; Silva et al., 2015).

The sociodemographic characteristics at baseline such as age, gender, and ethnicity in individuals with and without T2DM can alter the postprandial metabolic profiles (Cocate et al., 2011; González-Ortiz et al., 2006; R. C. Reynolds et al., 2009). Besides, the diabetes status of T2DM need to be taken into consideration as both fasting glucose and HbA1c level were associated with postprandial hyperglycemia (Lim et al., 2017). The nutritional status at baseline such as anthropometry measurements, dietary intake, GI and glycemic load (GL), and physical activity level in individuals with and without T2DM can influence postprandial metabolic response when consuming meals differing in GI (Ajala et al., 2013; Bae et al., 2018; Barakatun Nisak et al., 2010; Bell et al., 2015; Chandalia et al., 2000; Sun et al., 2014; Wolever et al., 2013).

The confounding factors that were controlled during the study included the test meal composition and macronutrient distribution (R. C. Reynolds et al., 2009). Before the day of the test, the duration of fasting, restriction in consumption of a large portion of food, nuts, legumes, and alcohol, and strenuous physical activity level the day before

individuals with and without T2DM consumed test meal were controlled (Barakatun Nisak, Ruzita, et al., 2009; Mottalib et al., 2016). To reduce the within-subject variability in T2DM, the weight, dietary intake, and physical activity level were measured before they consume the meals differing in GI (Jenkins et al., 1981).

The confounding factors that are not controlled in this study were the sleep quality and duration, ingestion of specific dietary protein, meal timing and orders, postmeal physical activity, and the type of functional food taken as a supplement by individuals with and without T2DM (Ch'ng et al., 2019; Cheng et al., 2016; Tricò, Filice, Trifirò, et al., 2016).

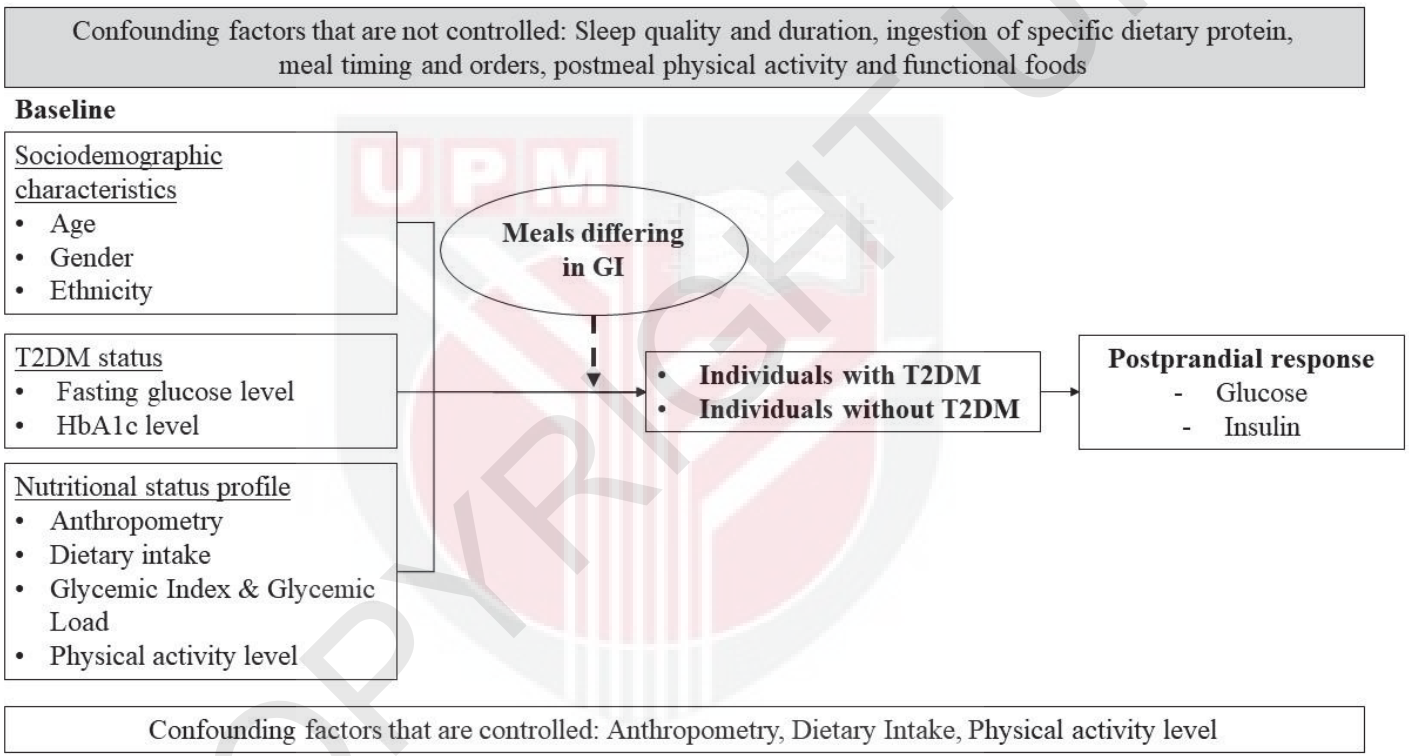

Figure 1.1: Conceptual framework

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