ORIGINAL ARTICLE

Effects of Modified Breakfast Meal on Postprandial Glucose and Insulin Levels in Individuals with and without Type 2 Diabetes

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ABSTRACT

Introduction: The postprandial (PP) response to breakfast meals varying in carbohydrate and fat quality remains understudied. Conventional Breakfast (CB) aligns with medical nutrition therapy for Type 2 *Diabetes mellitus* (T2DM), while Modified Breakfast (MB) represents a structured nutrition plan. This study aimed to (i) compare postprandial glucose and insulin levels between individuals with and without T2DM following CB and (ii) evaluate the differences in postprandial glucose and insulin responses to CB and MB in T2DM patients. **Materials and methods:** Parallel group comparison was performed on 40 subjects (T2DM=20 and without T2DM=20), matched by age and sex, and a randomised crossover trial was conducted on 20 subjects with T2DM. The T2DM subjects consumed both meals in a crossover manner, and those without T2DM were only given CB. Foods were consumed within 15 minutes, following 8-10 hours of overnight fasting. Blood samples were collected at fasting and hourly within 4-hours after the meals. **Results:** Using ANCOVA, the PP glucose response over the 4-hour period was significantly higher in individuals with T2DM compared to those without T2DM (431.98±191.71 versus 100.25±48.69, $p < 0.001$) for CB. Among T2DM subjects, there was no significant difference between CB and MB on PP glucose, but MB produced lower insulin responses compared to CB at 3-hour (27.70±13.70 versus 41.57±18.55,$p < 0.05$) and 4-hour (19.67±10.34 versus 31.68±19.93,$p< 0.05$). **Conclusion:** MB produced comparable 4-hour PP glycaemic responses to CB but with a lower insulin response. Future studies focusing on the incretin hormones after consumption of both test meals are worth investigating.
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Keywords: Hyperglycemia, Nutrition therapy, Glycaemic index, Monounsaturated fatty acids, Type 2 *diabetes mellitus*

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INTRODUCTION

Type 2 *Diabetes mellitus* (T2DM) is a significant health concern worldwide, with 60% of diabetes patients live in Asian region (1,2). Malaysia has a higher prevalence of T2DM (16.8%) when compared to its neighbouring countries, such as Singapore (14.2%) and Thailand (8.3%) (1). Glycaemic control in T2DM patients globally are inadequate with only 43% achieving the HbA1c target of < 7% (3). In South-East Asia region only 12-32% glycaemic target were achieved (4,5).

Fasting and postprandial (PP) blood glucose levels is crucial for evaluating daily glycaemic fluctuations and their impact on overall glycaemic management. Mounting evidence demonstrated unlike fasting blood glucose, PP glycaemic response among Asians tends to be higher than Caucasians, when compared to the same foods ingested (6,7). Two-hours PP glycemia of most Asian T2DM patients exceeds the optimal target of 7.8 mmol/L despite having an optimal fasting glucose level (8). Malaysia has the highest level of PP glycaemic average in South-East Asia with 13 mmol/L (5). Persistent

high PP glycemia has been associated with oxidative stress, resulting in microvascular, macrovascular complications, and cardiovascular events in individuals with and without T2DM (8–10). Thus, managing PP glycemia of T2DM is a prime of interest.

In terms of diabetes nutrition, significant rise in postprandial (PP) glycemia is impacted by intake of dietary carbohydrates, with both the amount and type of carbohydrates playing a role in affecting PP glycaemic levels. (11). According to medical nutrition therapy (MNT), meal for T2DM consists 30-50 g of carbohydrate (approximately three carbohydrate exchanges - one exchange =15 g of carbohydrate), high fibre, low fat, and sufficient protein (12). Dietetic counselling places particular emphasis on breakfast due to its potential impact on an individual's postprandial (PP) levels throughout the day. In Malaysia, bread is identified as a prevalent source of carbohydrates for breakfast. (13–15). There are various types of bread with tested glycaemic index (GI) values available in the Malaysian market (13). Even though having low GI bread as a breakfast meal has been shown to improve acute PP glycemia and insulinemia, white bread is still the most common and affordable choice (15,16). As part of T2DM patients' nutrition meal plan, dietetic counselling helps them to combine white bread with lower GI sources such as milk to reduce PP glycaemic impact (11).

In addition, addressing the high-carbohydrate nature of Asian diets cannot be adequately achieved solely by reducing carbohydrate intake through traditional meal plans (14). Hence, the inclusion of diabetes-specific formula (DSF), which has a balanced macronutrients composition, high fibre and monounsaturated fatty acids (MUFA) content and low GI, into the breakfast meal may provide an advantageous alternative meal plan for people with diabetes (17–19). The beneficial effects of DSF on PP glycaemic, insulin, glucagon-like peptide-1 (GLP-1) levels and cardiometabolic parameters have been well established (17–20). DSF can be incorporated in food intake as meal replacements or together with conventional foods, to assist in weight management and calorie counting (19,20).

Most previous studies either compared a single meal versus DSF (17,18) or meals that were purposely designed to have low and high GI (15,16). However, there were no studies that specifically evaluated the PP metabolic effects of two meal plans that both adhere to MNT for T2DM. This study included two distinct designs and populations to fill this gap. First, the parallel group comparison of conventional breakfast (CB) between subjects with and without T2DM helped provide a baseline to understand the extent of metabolic dysregulation in T2DM subjects by comparing their response to those without T2DM. Second, the randomized crossover trial within the T2DM group allowed us to compare the effects of CB and a modified breakfast (MB), which was constructed with diabetes-specific products such as DSF and whole grain bread, ensuring that variability was minimized by using the same subjects for both meal comparisons. This combined approach allowed the study to i) to compare the PP glucose and insulin levels in individuals with and without T2DM following a CB meal through the parallel comparison design and; ii); and To compare the effects of MB meal and CB meal on PP glucose and insulin responses of T2DM subjects using the crossover design. Together, these methods provide a comprehensive analysis of how different breakfast compositions affect both glycemic and insulin responses, enhancing the applicability of the findings to clinical practice.

MATERIALS AND METHODS

Study Design and Study Population

This study employed a combined design, utilizing both a parallel comparison and a randomized crossover trial, to comprehensively assess the effects of breakfast meal composition on postprandial glucose and insulin responses in subjects with and without Type 2 *Diabetes mellitus* (T2DM). The parallel design was used to evaluate postprandial responses to the conventional breakfast (CB) in two distinct groups: subjects without T2DM and with T2DM. The rationale for this approach was to independently examine the metabolic differences between these groups, particularly in their ability to manage postprandial glucose. The parallel design allowed for the identification of baseline differences in postprandial glucose and insulin responses between subjects with normal glucose metabolism and those with T2DM. This comparison provides a clearer understanding of how T2DM alters the physiological response to a standard meal, using the non-diabetic group as a reference point.

The randomized crossover design was employed specifically for the T2DM group. In this phase, each subject served as their own control, consuming both the conventional breakfast (CB) and the modified breakfast (MB) in a randomized order. The justification for this design lies in its ability to reduce inter-individual variability, thereby providing a more precise comparison of the effects of the two different meal compositions on postprandial responses. By comparing the same subject's response to both meals, the crossover design ensures that observed differences are attributable to the meal intervention rather than to individual differences in insulin sensitivity or other metabolic factors.

The study was conducted at the Endocrine Laboratory of Hospital Canselor Tuanku Muhriz (HCTM) UKM, Cheras, Kuala Lumpur, Malaysia from July 2019 to February 2020. Ethical approval was obtained from internal institutional research ethics committee (Project code: FF-2019-199, UKM) and subjects provided their informed consent before study participation.

The T2DM group consisted of 20 subjects aged 30-50 years, with a confirmed diagnosis of T2DM, BMI range of 18.5-35.0 kg/m , HbA1c of 6.5-10.0%, and were treated with stabilized dose of oral-antidiabetic (OAD) drugs in the past three months before the study. Subjects were excluded if they presented with clinically significant cardiovascular, renal or liver diseases, had impaired thyroid or liver function, were smoking, pregnant, lactating, on insulin therapy or certain OAD drugs (DPP-4 inhibitors, GLP-1 receptor agonists and acarbose), regularly used hormones or anti-inflammatory medications and had food intolerances or allergies.

On the other hand, 20 subjects without T2DM with inclusion criteria of 18.5-35.0 kg/m BMI, random blood glucose of < 7.8 mmol/L (irrespective of the timing of prior meals), and without a family history of diabetes were grouped. They were matched for age (±5 years), sex and ethnicity to the T2DM subjects.

Test Meals

A structured nutrition plan for diabetes emphasizes on controlling blood sugar level while ensuring balances intake of nutrition. The structured nutrition plan emphasizes on carbohydrate management, balanced meals, portion control and glycemic index of foods (21). In this study, test meal comprises of of two types of breakfast meals (CB and MB) with 30-50 g of carbohydrate, low in total fat (low GI=37%, high GI=23%), total protein (20%), and contributed to ~300 kcal/meal (12). The CB meal is a commonly prescribed breakfast option in the clinic, designed as per MNT for T2DM (Table I) (12). The MB meal was designed to match the calorie as per CB, but mimic the structured nutrition plan. The structured nutrition plan of MB substituted white bread with whole-grain bread, and milk with DSF. The DSF is composed of tapioca dextrin, 50% whey protein, 50% potassium caseinate from cow's milk, a fibre blend of acacia gum, fructo-oligosaccharides, and inulin, and a fat blend of high oleic sunflower, low erucic acid rapeseed, and sunflower oil. The inclusion of DSF in MB meal reduced the carbohydrate, GI and GL values and increased the protein, MUFA and fibre content (Table I).

Table I: Nutritional Composition of CB and MB Meal

	Conventional Breakfast meal	Modified Breakfast meal
Meal Content (serving)	- Skim milk powder (Sunlac®, New Zealand); 25g - White bread (Gardenia®); two slices - Margarine (Naturel®), two teaspoons	- Diabetes-specific formula powder (Nutren Diabetik, Nestle®); 27.5g (4 scoop) - Wholegrain bread (Gardenia®); two slices - Margarine (Naturel®), two teaspoons
Energy (kcal)	299	325
Carbohydrate (g)	43.9	36.1
Protein (g)	13.4	15.5
Fat (g)	7.5	12.9
SFA (g)	2	2.3
(% from total kcal)	(6%)	(6%)
MUFA (g)	3.2	6.8
(% from total kcal)	(10%)	(19%)
PUFA (g)	1.8	3.2
(% from total kcal)	(5%)	(9%)
Dietary Fibre (g)	1.4	6.3
Total GI	66 (Medium GI)	42 (Low GI)
Total GL	29 (High GL)	15 (Medium GL)

SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids; GI: Glycaemic index; GL: Glycaemic load

The meals were prepared on the morning of the test, portioned and served at room temperature. The GI and GL for both test meals were calculated based on the formula below (15):

Meal GI = $\sum\{[GI_{Food\ A} \times g\ available\ CHO_{Food\ A}] + [GI_{Food\ B} \times g\ available\ CHO_{Food\ B} + \ldots\}$/total g avail CHO]

Meal GL = GI x CHO (g) content per portion / 100

Where GI is the glycaemic index, CHO is the carbohydrate amount (g), and GL is the glycaemic load

The calculated difference in GI value between the meals (CB; GI = 66, MB; GI = 42) was 24 units and was expected to produce a significant impact on PP glucose and insulin responses.

Milk (skim or DSF) was included in the meal plan of this study to ensure adequate protein intake. Milk and dairy products are nutritious foods rich in calcium, vitamins (such as B2, B12 and D) and have low GI regardless of their fat content, hence should be part of diabetes MNT (22). Despite that, milk and dairy products are not commonly consumed in South-East Asian countries and the consumption is relatively low when compared to Western countries (14). Consumption of milk should be recommended to people with T2DM as low dairy or milk intake is associated with poor glycaemic control (23). The inclusion of milk in meal plans helps to regulate the blood glucose responses as shown in this study. In addition, the insulinemic properties of milk in relations to amino acids may help to increase insulin production, resulting in the reduction of PP glucose levels (17,18,24).

Study Procedures

All subjects were asked to maintain their lifestyle habits and body weight throughout the study period. A research dietitian evaluated the anthropometric measurements, dietary intake, and physical activity level at each study visits to check to control within subject variation.

Subjects without T2DM were required to attend one study visit for CB consumption to enable physiological comparison on PP glycaemic and insulin responses

CONTINUE

with T2DM subjects. In addition, subjects with T2DM were randomly assigned in a crossover manner for two different study visits with a one-week washout period in between. One week washout period was used to avoid carryover effect. This enabled comparison on the effect of DSF inclusion into breakfast meal plan among T2DM subjects.

A day before test, subjects were reminded to refrain from additional exercise, eat as usual and not to consume legumes to avoid any confounding effects on the PP response (15,17). Subjects were required to fast for 8-10 hours, and to arrive at study centre 0830 in the morning. The T2DM subjects were asked to withhold their OAD drug during the test day. The testing procedures utilised the meal-challenge test technique in which the fasting blood was obtained at 0 minutes, followed by consuming the test meals at a comfortable pace of 15 minutes. Then, the subsequent blood samples were obtained at 30 minutes, 1, 2, 3, and 4 hours. Plain water (250ml) was served together with the meal. Subjects remained sedentary throughout 4 hour study period.

At each time point, blood samples (4ml) were collected into tubes containing potassium oxalate and sodium fluoride, intended for plasma glucose analysis using the glucose oxidase method (Abbott® ARCHITECT c16000). Blood samples (3ml) for serum insulin measurement were collected into serum separator (SST) tubes at each timepoint and analysed using the immunoassay method (Elecsys® COBAS® e411). The incremental area under the curve (iAUC) between 0 and 4 hours for plasma glucose and serum insulin were calculated for each subject (25). Previous studies conducted calculated the incremental area under the curve (iAUC), focusing solely on levels above fasting (15,17,18). Additionally, it was recommended to utilize iAUC measurement, as the total area under the curve (tAUC) is less sensitive in detecting differences in responses between foods (25).

Sample Size

Based on a sample size calculation, a minimum of 20 T2DM subjects was required to detect 2.0 mmol/L significant differences in PP glucose (26) at 80% power and 95% confidence interval (27). The differences in 2mmol/L were considered as clinically significant based on previous study (26). An equal number of subjects without T2DM were recruited for parallel comparison. It was determined that the number of subjects was sufficient to detect the expected differences in PP response between individuals with and without T2DM (28). An attrition rate of 20% was considered based on a review of 71 randomized controlled trials (29).

Study Assessment

In anthropometric measurements, weight was measured using a Tanita digital weighing scale, while height was measured using a SECA Bodymeter 206 Germany. Two measurements were taken and the average readings were recorded to the closest 0.1 kg or 0.1 cm, respectively. Blood pressure was measured twice using an automated blood pressure monitor and the average reading was recorded. For dietary intake, a 24-hour dietary recall was recorded during each visit and analysed using the Nutritionist Pro™ software. The amount of foods and drinks were estimated according to standard household measurement including glasses, cups, bowls, plates and spoons using Malaysian Atlas of Food Exchanges and Portion Sizes. Subjects were required to provide the cooking methods and brand names if needed. 24-hour diet recall were used to control within subject variation throughout study period.

The International Physical Activity Questionnaire (IPAQ) short form was used to assess subject's physical activity level by calculating the sum of metabolic equivalent of task (MET) minutes/week scores. The MET score is defined as the energy required to accomplish physical activity based on its intensity and accounting for the duration and frequency of the activities (30).

Statistical Analyses

Statistical analyses were performed using IBM SPSS (Version 24). The variable distribution was examined, and the skewed variables were analysed using non-parametric tests. The quantitative analysis following normal distribution was reported as mean ± standard deviation unless otherwise specified. The mean differences between the two groups were analysed using an independent t-test. Analysis of covariance (ANCOVA) was used to compare the baseline characteristics and the iAUC glucose and insulin levels of individuals with and without T2DM. As BMI considerably varied between the groups, it was included in the analysis as a covariate. A Chi-square test was used to analyse for categorical data, such as sex. Repeated-measure analysis of variance (ANOVA) was used to compare the PP glucose and insulin between subject groups at five different time points, with consideration of inter-variability and intra-variability between subjects. All the analyses were considered significant if the $p < 0.05$.

RESULTS

A total of 2,606 subjects with T2DM were screened (Fig. 1) and 60 subjects fulfilled the study criteria. The main reason for exclusion were age (n = 1,353), HbA1c level (n = 508), BMI > 35 kg/m^2 (n = 100) and use of drugs such as GLP-1 or DPP-4 (n = 585). A total of 20 T2DM subjects consented to participate and were recruited to join the study. Another 20 subjects without T2DM were recruited and matched with T2DM subjects according to age, sex and ethnicity.

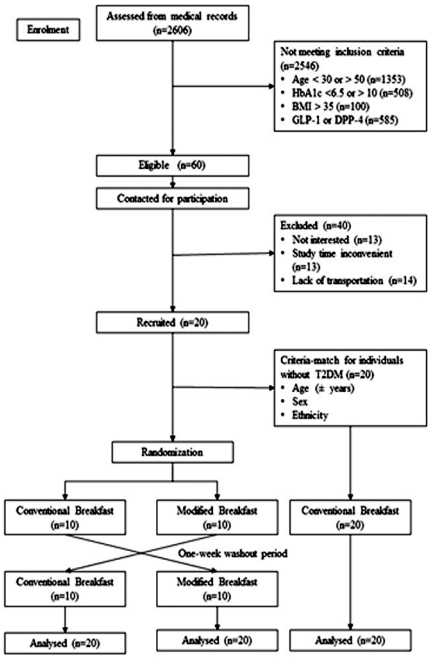

Figure 1: Screening Enrolment Based on the Consolidated Standards of Reporting Trials (CONSORT) Statement
*** Indicates significant difference between the subject groups at the specific timepoint (p<0.05)**
**** Indicates significant difference between the subject groups at the specific timepoint (p<0.001)**

Majority of subjects were female (55%) with age between 45 and 50 years old (42.5%). Among T2DM subjects, mean duration of diabetes was 6.3 ± 4.0 years (Table II). Subjects were on metformin and sulphonylureas (45%), metformin and sodium-glucose co-transporter-2 inhibitors (20%), metformin alone (15%), or a combination of three medications (20%). Most of subjects with T2DM had additional co-existing conditions, such as hypertension and dyslipidemia (69%), in contrast to those without T2DM (10%).

Baseline subjects' characteristics were summarised into Table II. T2DM subjects had a significantly higher weight (79.7 kg) and BMI (30.2 kg/m^2) compared to a subjects without T2DM (weight = 69.6 kg; BMI = 26.6 kg/m^2, $p < 0.05$) (Table II). BMI was used as a covariate to adjust the results for blood pressure, biochemical analysis, dietary intake, and physical activity. Subjects with T2DM showed a significantly higher systolic and diastolic blood pressure, fasting blood glucose, HbA1c, and homeostasis model assessment of insulin resistance (HOMA-IR), after adjustment of BMI ($p < 0.001$). Subjects with T2DM also had a higher consumption of fibre than those without T2DM ($p < 0.05$). Energy and macronutrients intake, and physical activity level between subjects with and without T2DM, were comparable (Table II).

Table II: Baseline Characteristics of Subjects with and without T2DM measured at the 1st visit

	Subjects with T2DM (n = 20)		Subjects without T2DM (n = 20)	
	n (%)		n (%)	
Sex				
Men	9 (45)		9 (45)	
Women	11 (55)		11 (55)	
	Mean ± SD	**95% CI**	**Mean ± SD**	**95% CI**
Duration of T2DM diagnosis (years)	6.3 ± 4.0	-	N/A	-
Age	43.7 ± 6.2	-	41.4 ± 5.4	-
Anthropometry				
Height	161.7 ± 9.5	157.3-166.1	161.4 ± 6.7	158.3-164.5
Weight[a]	79.7 ± 16.1	72.2-87.2	69.6 ± 12.5	63.8-75.5
BMI (kg/m²)[a]	30.2 ± 3.7	28.5-31.9	26.6 ± 3.9	24.8-28.5
Blood Pressure				
Systolic BP[b]	136 ± 11.9	131-140	123 ± 9.9	118-127
Diastolic BP[b]	92 ± 12.7	87-98	75 ± 10.3	69-80
Biochemical Data				
Fasting glucose (mmol/L)[b]	7.3 ± 1.6	6.7-7.9	4.9 ± 0.5	4.4-5.5
HbA1c (%)[b]	7.9 ± 1.1	7.1-8.7	4.6 ± 2.0	3.8-5.4
Fasting insulin (uIU/ml)	19.4 ± 18.4	12.9-26.0	15.3 ± 11.2	8.7-21.8
HOMA-IR[a]	5.6 ± 3.6	4.2-6.9	3.4 ± 2.8	2.0-4.7
Dietary Intake				
Energy (kcal)	1496 ± 487	1289-1703	1312 ± 371	1105-1519
Carbohydrate (g)	195 ± 74.7	163.5-227.2	183 ± 57.8	150.9-214.7
% Carbohydrate in kcal	52 ± 7.6	49-56	56 ± 5.9	52-59
Protein (g)	55 ± 21.5	46.5-62.9	48 ± 11.8	39.5-55.9
% Protein in kcal	14 ± 3.2	13-15	15 ± 2.1	14-16
Fat (g)	56 ± 20.7	47.1-64.3	43 ± 14.2	34.8-51.9
% Fat in kcal	33 ± 6.9	30-36	29 ± 5.6	26-32
Fibre (g)[a]	4.6 ± 3.6	3.2-5.9	2.2 ± 1.5	0.8-3.5
Physical Activity				
METs (min/week)	13640 ± 9871	8972-18309	15717 ± 9536	11049-20386
Sedentary activity (mins)	299.2 ± 181.5	196.3-402.1	355.2 ± 239.2	252.3-458.1

[a] $p < 0.05$; [b] $p < 0.001$
N/A: Not applicable; HbA1c: Glycosylated haemoglobin; BMI: Body mass index; HOMA-IR: Homeostasis model assessment of insulin resistance; MET: Metabolic equivalent of the task; Sedentary activity refers to the time spent in sitting
Blood pressure, biochemical data, dietary intake and physical activity were adjusted with BMI as covariate

Comparison of Postprandial Glycaemic and Insulinemic Response in Individuals with and without T2DM After Consuming CB Meal

The fasting blood glucose (8.1±2.1 mmol/l) and insulin level (17.5±20.3 uIu/ml) of subjects with T2DM were significantly higher than subjects without T2DM (4.8 ± 0.5 mmol/L and 9.2 ± 6.2 uIu/ml, respectively; $p < 0.05$) before consuming CB meal. During 4 hours study periods, blood glucose level at each time point in subjects with T2DM was significantly higher when compared to subjects without T2DM ($p < 0.001$) (Fig. 2(a)). The blood glucose level rose significantly ($p < 0.001$) for T2DM subjects and peaked at 1 hour for both groups. Average PP glucose of T2DM subjects at 2 hours was 11 mmol/L. At 4 hours post-meal, subjects with T2DM had a significantly higher glucose iAUC than subjects without T2DM (Table III).

Subjects with T2DM had a significantly lower insulin levels at 30 minutes ($p < 0.05$) and a higher insulin level at 3 and 4 hours ($p < 0.001$) than subjects without T2DM (Fig. 2(b)). The insulin level in a subjects with and without T2DM peaked at 1 hour and 2 hours time point. The insulin iAUC at 4 hours did not differ significantly between both groups (Table III).

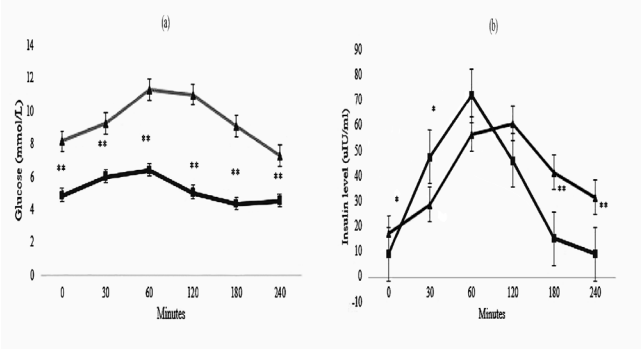

Fig. 2: Changes in (a) Postprandial Glucose and (b) Postprandial Insulin Levels in Individuals with (n=20) and without T2DM (n=20) after Consuming a Conventional Breakfast Meal
*** Indicates significant difference between the meals at the specific timepoint ($p<0.05$)**

Table III: Incremental Area Under the Curve (iAUC) 0-240 minutes for Glycemia and Insulinemia in Individuals with (n = 20) and without T2DM (n = 20) after Consuming a Conventional Breakfast Meal

	Subjects with T2DM (n = 20)		Subjects without T2DM (n = 20)	
	Mean ± SD	95% CI	Mean ± SD	95% CI
Glucose (mmol.L/min)[b]	431.98 ± 191.71	367.94-496.02	100.25 ± 48.69	36.21-164.29
Insulin (uIU.ml/min)	5494.87 ± 3400.01	3226.93-7762.81	6691.80 ± 5780.82	4423.86-8959.74

[b] $p < 0.001$
Glucose iAUC and insulin iAUC were adjusted with BMI as covariate

Comparison of Postprandial Glycaemic and Insulinemic Responses to CB and MB Meals in T2DM Subjects

The glucose and insulin levels of subjects with T2DM before consuming CB and MB were comparable (Glucose = 8.1 ± 2.1 vs 8.1 ± 2.5 mmol/L, Insulin = 17.5 ± 20.3 vs 16.6 ± 14.1 uIU/ml). After consumption of both meals, blood glucose level increase significantly ($p < 0.001$) and peaked at 1 hour (Fig. 3(a)). The PP insulin response after consuming MB meal was significantly higher at 30 minutes when compared to CB. However, insulin PP response at 3 dan 4 hours following MB meal was significantly lower ($p < 0.05$) when compared to CB (Fig. 3(b)). The iAUC for glucose and insulin at 4 hours after CB did not differ significantly from MB (Table IV).

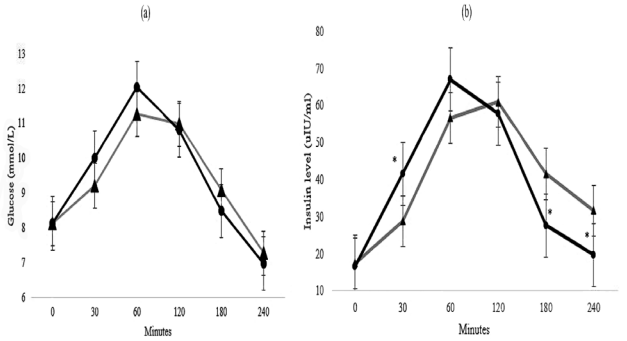

Fig. 3: Effect of CB and MB Meals on (a) Postprandial Glucose and (b) Postprandial Insulin Responses Over 4hr Period in subjects with T2DM (n=20 in each group)

Table IV: Incremental Area Under the Curve (iAUC) 0-240 minutes for Glycemia and Insulinemia Between CB and MB Meals in subjects with T2DM (n = 20 in each group, cross-over design)

	CB meal (n = 20)		MB meal (n = 20)	
	Mean ± SD	95% CI	Mean ± SD	95% CI
Glucose (mmol.L/min)	431.98 ± 191.71	367.94-496.02	429.93 ± 191.91	340.12-519.75
Insulin (uIU.ml/min)	5494.87 ± 3400.01	3226.93-7762.81	5840.93 ± 2828.63	4517.09-7164.76

CB: conventional breakfast; MB: modified breakfast

DISCUSSION

This study compared the PP glucose and insulin levels in subjects with and without T2DM to understand the physiological responses following a CB meal which was a commonly consumed breakfast in Malaysian population. Consistent with previous literature, this study showed subjects without T2DM had lower glucose and insulin responses when compared to subjects with T2DM subjects (8,28,31). The PP glucose response was found to be significantly higher in subjects with T2DM at all time points.

About 85% of the T2DM subjects in this study did not meet the recommended PP glucose level of < 7.8 mmol/L at 2 hours (1). Subjects with T2DM were unable to achieve the targeted PP glucose level because of the delay in early-phase insulin secretion, which reduces the ability to regulate blood glucose response (28,32). This impairment may cause late hyperinsulinemia, which can lead to an abnormal rise in glucagon levels and increase production of endogenous liver glucose, thereby exacerbates the PP glycaemic control (28,32). In this study, there was an evident delay in the insulin peak among subjects with T2DM compared to those without T2DM. The rapid rise of insulin secretion among subjects without T2DM returned the blood glucose level to fasting condition at approximately three hours post-consumption of the CB meal.

On the other hand, a head-to-head comparison of breakfast meal plan (CB vs MB), varying in quality of carbohydrate (GI, GL values and fibre) and fat (MUFA) were performed among T2DM subjects. The CB and MB meal showed a comparable effects on PP glucose levels at each time point. This finding is contrary to a previous study, which reported lower PP glucose response after consumption of meal low in carbohydrate and GI, also high in protein and fibre among Malaysian adults with T2DM (15). This discrepancy could be attributed to the innate objectives of the studies and therefore the differing meals tested. The past study (15) compared two meals that were different in GI (low GI=36, high GI=70), whereas the current study compared a commonly prescribed breakfast meal with a meal constructed with diabetes-specific products. Even though both meals in the current study adhered to the Malaysian MNT recommendations for meal prescriptions, the inherent formulation difference between the products used led to variations in nutritional composition.

Meanwhile, the ratio of whey to casein in DSF is higher than in milk. Whey protein has been shown to promote early-phase amino acids and GLP-1 secretion, which are necessary to stimulate insulin secretion among T2DM (18,24). In this study, the effects of early-phase insulin secretion by DSF can be observed at 30 minutes after consumption of MB meal. However, MB elicited a lower insulin response than CB at 3 and 4 hours time point.

These findings are critical as subjects with T2DM showed an excessive rise in PP glucose responses that were associated with delayed early-phase insulin secretion. Early peak of insulin secretion was observed following MB mimics the secretion pattern observed in non-T2DM subjects. Thus it can be suggested consistent intake of MB could potentially improve pancreatic β-cells function (33). Despite no difference in PP glucose responses between MB and CB, the significantly lower insulin responses at 3 and 4 hours post-consumption could prove beneficial to the β-cell function in the long term and warrants further investigation (33). This is because, the persistent elevation of insulin concentrations may downregulate the insulin receptor, causing insulin resistance (8). In contrast, long term reduction of PP hyperinsulinemia may indicate a reduction in oxidative stress, thereby lowering cardiovascular events and prevent the deterioration of glycaemic control (31,32).

Aside from that, the findings of the current study also contradicted a meta-analysis that reported DSF containing at least 20% MUFA and 40% fat from total energy have beneficial effects on PP glycemia and insulin iAUC in people with T2DM compared to the standard formula (34). Another previous study shows, T2DM subjects who consumed DSF displayed lower AUC glucose and insulin than ones who had isocaloric meal comprised of cornflakes and milk (17). The author ascribed the results to the high MUFA content (27% from total energy) in DSF compared to the isocaloric meal. Interestingly, the favourable effects of MUFA on PP glycemia and insulinemia as such were not observed in the current study.

Aside from fat quality, the difference in carbohydrate quality is also of importance because the GI value in MB meal was lower than CB by 24 points (18,25). In a study comparing the effects of oats and two DSFs, the results showed no difference in PP insulinemia at 2 and 4 hours (18). The author acknowledged that the higher GI and carbohydrate amount in oatmeal could attenuated the difference in PP insulinemia (18).

An earlier acute study done in Malaysia used a locally available food to maximise the GI differences between two meal plans reported difficulties in regulating the percentage of carbohydrate and protein (15). It was noted that the evaluation of food or nutrient impact in PP studies should be performed by modifying one variable at a time, in order to identify the predictor of the effect. Nevertheless, the feasibility of matching test meal's macronutrient composition is low when one has to use available market products. While the use of sucrose and isomaltulose based solutions or formula can control many of the variables (35), the translatability of practice remains questionable.

This study has several limitations. A better-matched weight and BMI between individuals with and without T2DM would have eliminated any residual confounding effects on the PP response differences. However, the results remained unchanged even after controlling for BMI.. The PP response to MB was not tested in those without T2DM. This investigation provides valuable data on differential PP metabolic response following both breakfast meal plans in normoglycaemic subjects. In addition, the individuals without T2DM in the current study were overweight and obese, thus at risk of experiencing impaired glucose tolerance. These results would have been a useful guide in their dietary intake management. The lack of an oral glucose toletance test

(OGTT) in this study also limits our ability to account for any intra-individual variations in PP glycaemic and insulinemic responses. Furthermore, the 24-hour dietary recall method used may not provide a comprehensive review of subjects' dietary intake. The ratio of under-reporting was found to be equally high in both groups, consistent with other dietary studies in Malaysia (4,14). Apart from that, the effects of MB meal on incretin hormones, free fatty acids, and the body's food response were not known, hence limiting the ability to provide a definitive conclusion.

In addition, this is a pilot study, the findings should be interpreted with caution. The small sample size and short duration limit the generalizability of the results. Therefore, further research is needed to confirm these outcomes in larger, more diverse populations and over extended periods. In clinical dietetics, this pilot study provides preliminary evidence supporting the incorporation of structured nutrition plans, such as MB, into T2DM management strategies. Dietitians may consider recommending meal plans that not only focus on glycemic control but also optimize insulin response, contributing to more effective diabetes management in the long term.

Nonetheless, the study has several strengths, such as that the similarity of the provided meal plan in adherence to the current practice of encouraging "real-food" or an optimal combination of food, as opposed to recommending a dietary formula, with consideration of affordability and sustainability. These findings add practical relevance in the Malaysian setting. The crossover study design greatly minimises the within-subject variation, allowing for a more precise measurement of PP metabolic response.

CONCLUSION

This study demonstrated that subjects with T2DM produced significantly higher glucose and insulin response after consuming the CB meal compared to subjects without T2DM. In individuals with T2DM, the MB meal produced significantly lower insulin response at 3 and 4 hours post-consumption, but no significant difference in glucose levels compared to the CB meal. The results provide evidence for the appropriate inclusion of diabetes-specific products in optimizing the PP responses in individuals with T2DM. Both CB and MB meals are nutritionally suitable for T2DM. In continuity of this study, an investigation on the perturbations in metabolites using a metabolomics approach is currently underway to further clarify the underlying metabolic benefits of both standard-diabetes nutrition meal plans. Nonetheless, the benefits of MB should be unequivocally established before making it a preferred intervention choice in PP glycemia management as affordability and taste play an important role in adherence to dietary interventions.

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