

**ASSOCIATION OF BODY MASS INDEX (BMI), WAIST
CIRCUMFERENCE, AND BODY FAT PERCENTAGE WITH
GLYCAEMIC CONTROL AMONG PATIENTS WITH TYPE 2
DIABETES MELLITUS (T2DM) AT HOSPITAL PAKAR
UNIVERSITI SAINS MALAYSIA (HPUSM)**

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**SCHOOL OF HEALTH SCIENCES
UNIVERSITI SAINS MALAYSIA**

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by

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of the requirements for the degree
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**HUBUNGKAIT INDEKS JISIM TUBUH (IJT), UKUR LILIT
PINGGANG, DAN PERATUS LEMAK BADAN DENGAN KAWALAN
GLISEMIK DALAM KALANGAN PESAKIT DIABETES MELITUS
JENIS 2 (T2DM) DI HOSPITAL PAKAR UNIVERSITI SAINS
MALAYSIA (HPUSM)**

ABSTRAK

Diabetes melitus, terutamanya diabetes melitus jenis 2 (T2DM), merupakan salah satu masalah kesihatan awam global yang semakin meningkat. Indikator antropometri seperti indeks jisim tubuh (IJT), ukur lilit pinggang, dan peratus lemak badan sering digunakan bagi menilai adipositi; namun, hubungan antara indikator ini dengan kawalan glisemik masih menunjukkan dapatan yang tidak konsisten dalam pelbagai kajian. Kajian keratan rentas ini bertujuan untuk menentukan hubungan antara IJT, ukur lilit pinggang, dan peratus lemak badan dengan kawalan glisemik (HbA1c) dalam kalangan pesakit T2DM di Hospital Pakar Universiti Sains Malaysia (HPUSM). Kajian ini melibatkan seramai 94 pesakit T2DM berumur 19 tahun ke atas. Data dikumpulkan menggunakan borang pengumpulan data berstruktur melalui temu bual bersemuka, diikuti pengukuran antropometri menggunakan stadiometer SECA, pita pengukur tidak anjal SECA, dan penganalisis komposisi badan Tanita SC-240MA, serta pengambilan nilai HbA1c daripada rekod perubatan. Ujian korelasi Spearman digunakan untuk analisis statistik. Keputusan kajian menunjukkan tiada hubungan signifikan antara IJT dan HbA1c ($p = 0.765$), ukur lilit pinggang dan HbA1c ($p = 0.533$), serta peratus lemak badan dan HbA1c ($p = 0.644$), menunjukkan bahawa indikator

antropometri secara individu mungkin bukan peramal bagi kawalan glisemik dalam populasi ini. Gabungan beberapa ukuran antropometri dicadangkan untuk digunakan dalam amalan klinikal bagi memberikan penilaian status adipositi yang lebih menyeluruh. Indikator antropometri juga perlu ditafsirkan bersama faktor klinikal dan bukan klinikal lain bagi memahami kawalan glisemik dengan lebih baik. Kajian masa hadapan disarankan melibatkan saiz sampel yang lebih besar, pemboleh ubah pengganggu tambahan, serta reka bentuk kajian longitudinal untuk mengenal pasti hubungan kausal antara komposisi badan dan kawalan glisemik.

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ABSTRACT

Diabetes mellitus, particularly type 2 diabetes mellitus (T2DM), is one of the growing global public health concerns. Anthropometric indicators such as body mass index (BMI), waist circumference, and body fat percentage are commonly used to assess adiposity; however, the relationship between these indicators and glycaemic control remains inconsistent across studies. This cross-sectional study aimed to determine the association of BMI, waist circumference, and body fat percentage with glycaemic control (HbA1c) among patients with T2DM at Hospital Pakar Universiti Sains Malaysia (HPUSM). A total of 94 T2DM patients aged 19 years and above participated in the study. Data were collected through face-to-face administration of a structured data collection form, followed by anthropometric measurements using a SECA stadiometer, a SECA non-elastic measuring tape, and a Tanita SC-240MA body composition analyser, as well as retrieval of HbA1c values from medical records. Spearman's rank correlation was used for statistical analysis. The results showed no significant association between BMI and HbA1c ($p = 0.765$), waist circumference and HbA1c ($p = 0.533$), or body fat percentage and HbA1c ($p = 0.644$), indicating that individual anthropometric indicators may not be predictors of glycaemic control in this population. It is

suggested that a combined use of anthropometric measurements may provide a more comprehensive assessment of adiposity status in clinical practice. Anthropometric indicators should also be interpreted alongside other clinical and non-clinical factors to better understand glycaemic control. Future studies are recommended to include larger sample sizes, additional confounding variables, and longitudinal study designs to identify causal relationships between body composition and glycaemic control.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND OF STUDY

Diabetes mellitus, especially type 2 diabetes mellitus (T2DM), has become a common health problem worldwide due to its increasing prevalence (Akhtar et al., 2022). The International Diabetes Federation (IDF) reported that 9.3% of adults were living with diabetes in 2019 (Akhtar et al., 2022). This proportion is expected to increase to 10.2% by 2030 and 10.9% by 2045 if effective prevention efforts are not implemented (Akhtar et al., 2022). In Malaysia, the National Health and Morbidity Survey (NHMS) 2023 indicated that the prevalence of diabetes among adults was 15.6% (Institute for Public Health, 2024). Although this represented a slight decrease from 18.3% in 2019, the prevalence remained higher compared to 11.2% in 2011 and 13.4% in 2015, indicating an overall rising trend over time (Institute for Public Health, 2024). In this context, Kelantan reported a prevalence of 16.3% in 2023, which was higher than the national average (Institute for Public Health, 2024).

T2DM is a metabolic disorder characterised by insulin resistance and relative insulin deficiency (Galicia-Garcia et al., 2020). Maintaining appropriate blood glucose levels is important, as it helps to prevent both microvascular and macrovascular complications and supports overall disease control (Yachmaneni et al., 2023). Despite emerging therapies, many patients still experience poor glycaemic control. In Pasir Puteh, poor glycaemic control was observed in almost 80% of the T2DM subjects (Awang et al., 2020). Being overweight or obese is a major modifiable factor that contributes to insulin resistance and impairment of glucose metabolism (Abidin et al., 2023). A study in Malaysia reported increased body fat

mass, body fat percentage, and visceral fat area among diabetic subjects compared to non-diabetic subjects (Abidin et al., 2023).

Body mass index (BMI) is commonly used in clinical practice due to its simplicity and cost-effectiveness. However, it has several limitations. It cannot differentiate between fat and muscle and does not indicate fat distribution (Wu et al., 2024). Waist circumference can be more informative regarding abdominal fat, which is associated with insulin resistance and the risk of cardiovascular diseases (Ross et al., 2020). It has been suggested to be a better predictor of health outcomes than BMI in some studies (Ross et al., 2020). Body fat percentage may provide a more direct estimate of adiposity compared to BMI. Some studies found that it was linked to glycated haemoglobin (HbA1c) levels (Bower et al., 2017). This suggests it may be useful in reflecting glycaemic-related health risks.

Given the high prevalence of diabetes in Kelantan and the persistently poor glycaemic control among patients (Awang et al., 2020; Institute for Public Health, 2024), it was important to examine how different anthropometric indicators, including BMI, waist circumference, and body fat percentage, were associated with glycaemic control in this population.

1.2 PROBLEM STATEMENT

Despite various government initiatives, many T2DM patients in Kelantan still experience poor glycaemic control (Awang et al., 2020). Currently, anthropometric assessments primarily rely on BMI to screen for obesity; however, it has limitations, as it does not reflect body fat distribution or the associated metabolic risk (Wu et al., 2024). Other measurements, such as waist circumference and body fat percentage, may better indicate an individual's health status (Bower et al., 2017; Ross et al., 2020).

Although numerous studies have examined the relationship between these anthropometric indicators and glycaemic control, most have been conducted in non-local populations, and the availability of hospital-level data in Malaysia, especially in Kelantan, remains limited (Maulina et al., 2024; Deng et al., 2025). Local data are important because differences in ethnicity, lifestyle, and dietary patterns may influence body composition and glucose metabolism differently (Whitfield, 2024).

Moreover, previous studies have reported inconsistent findings on the association of BMI, waist circumference, and body fat percentage with glycaemic control among patients with T2DM. While some studies found significant associations (Bower et al., 2017; Zhen et al., 2022; Rahman et al., 2024), others did not find such associations (Oumer et al., 2022; Lin, 2024; Nomura et al., 2024). These inconsistent findings suggest that the association may vary across populations.

Furthermore, very few studies have measured all three indicators concurrently within the same population of T2DM patients (Han et al., 2019). Evaluating all three measurements may provide a better understanding of their relative associations with glycaemic control.

For these reasons, there was a need to conduct a study examining the association of BMI, waist circumference, and body fat percentage with glycaemic control in a local setting. This study investigated these anthropometric indicators in relation to glycaemic control, as indicated by HbA1c levels, among patients with T2DM at Hospital Pakar Universiti Sains Malaysia (HPUSM), Kelantan. The findings may contribute evidence to guide clinicians and dietitians in selecting appropriate anthropometric indicators for monitoring glycaemic control in clinical practice.

1.3 RESEARCH QUESTIONS

1. Is there a significant association between BMI and glycaemic control (HbA1c) among patients with T2DM at HPUSM?
2. Is there a significant association between waist circumference and glycaemic control (HbA1c) among patients with T2DM at HPUSM?
3. Is there a significant association between body fat percentage and glycaemic control (HbA1c) among patients with T2DM at HPUSM?

1.4 RESEARCH OBJECTIVES

1.4.1 GENERAL OBJECTIVE

To determine the association of BMI, waist circumference, and body fat percentage with glycaemic control (HbA1c) among patients with T2DM at HPUSM.

1.4.2 SPECIFIC OBJECTIVES

1. To assess the association between BMI and glycaemic control (HbA1c) among patients with T2DM at HPUSM.
2. To assess the association between waist circumference and glycaemic control (HbA1c) among patients with T2DM at HPUSM.
3. To assess the association between body fat percentage and glycaemic control (HbA1c) among patients with T2DM at HPUSM.

1.5 RESEARCH HYPOTHESES

1.5.1 HYPOTHESIS I

Null hypothesis (H_0): There is no significant association between BMI and glycaemic control (HbA1c) among patients with T2DM at HPUSM.

Alternative hypothesis (H_1): There is a significant association between BMI and glycaemic control (HbA1c) among patients with T2DM at HPUSM.

1.5.2 HYPOTHESIS II

Null hypothesis (H_0): There is no significant association between waist circumference and glycaemic control (HbA1c) among patients with T2DM at HPUSM.

Alternative hypothesis (H_1): There is a significant association between waist circumference and glycaemic control (HbA1c) among patients with T2DM at HPUSM.

1.5.3 HYPOTHESIS III

Null hypothesis (H_0): There is no significant association between body fat percentage and glycaemic control (HbA1c) among patients with T2DM at HPUSM.

Alternative hypothesis (H_1): There is a significant association between body fat percentage and glycaemic control (HbA1c) among patients with T2DM at HPUSM.

1.6 CONCEPTUAL FRAMEWORK

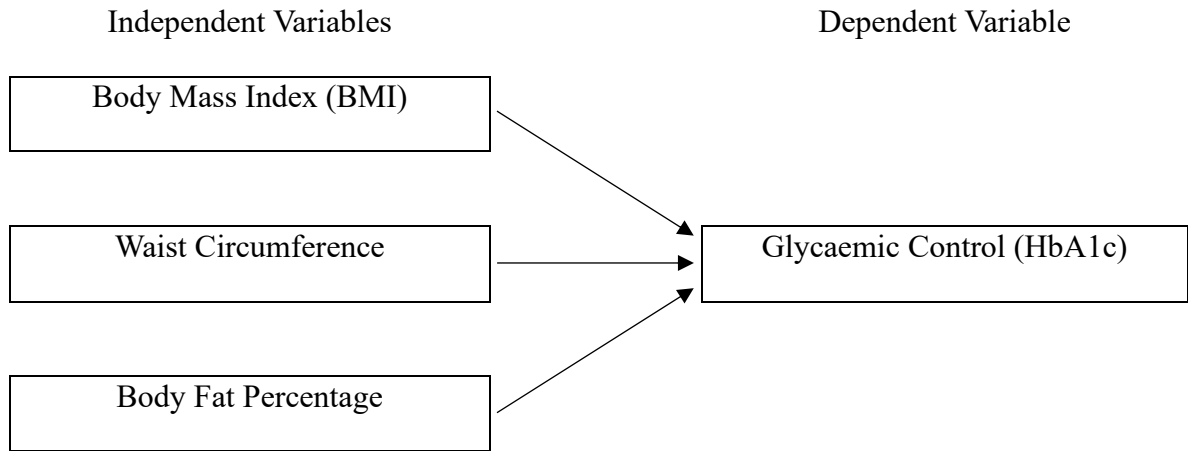


Figure 1.1: Conceptual Framework

This model illustrates the hypothesised relationship of BMI, waist circumference, and body fat percentage with glycaemic control among T2DM patients (Figure 1.1). BMI, waist circumference, and body fat percentage are the independent variables in this study, as they reflect overall adiposity, central adiposity, and body fat composition, respectively. They are commonly used indicators of body composition and fat distribution, which may influence insulin sensitivity and glycaemic control (Liau, 2024). The dependent variable in this model is HbA1c levels, which reflects long-term glycaemic control over the past two to three months (American Diabetes Association [ADA], 2024). It was hypothesised that higher BMI, waist circumference, or body fat percentage may be associated with poorer glycaemic control (higher HbA1c levels).

Although this study focused on BMI, waist circumference, and body fat percentage as the main independent variables, previous literature has shown that other factors may also influence glycaemic control, such as age, sex, duration of diabetes, medication use, dietary pattern, physical activity, and comorbidities (Haghighatpanah et al., 2018; Sheleme et al.,

2020). These factors may act as potential confounders in the relationship between anthropometric indicators and glycaemic control. However, due to the predefined scope and resource limitations, only selected variables were included in this study to describe the characteristics of the participants and for additional analysis where appropriate. Future studies are recommended to include more confounding variables to better understand the determinants of glycaemic control.

CHAPTER 2: LITERATURE REVIEW

2.1 OVERVIEW OF TYPE 2 DIABETES MELLITUS

T2DM is a chronic metabolic disease that impairs glucose metabolism, whereby insulin resistance and progressive loss of pancreatic β -cell function raise blood glucose levels (World Health Organization [WHO], 2024). It is the most common type of diabetes among adults, accounting for more than 90% of all diabetes cases worldwide (IDF, 2024). The increase in T2DM is attributed to factors such as urbanisation, population ageing, growing prevalence of overweight and obesity, and changes in lifestyle such as poor diet and low physical activity (IDF, 2024).

Recent data indicated that over 800 million adults globally had diabetes (WHO, 2024). This represented a more than fourfold increase compared to the figure recorded in 1990 (WHO, 2024). The regional differences were large. Most people with diabetes were living in low- and middle-income countries (IDF, 2024). A large number of adults were unaware that they had diabetes, which led to delays in early treatment and prevention of complications (IDF, 2024).

Diabetes remains a major public health problem in Malaysia. The prevalence of diagnosed diabetes among adults was high at 15.6% in NHMS 2023 (Institute for Public Health, 2024), while the National Diabetes Registry (NDR) 2023 also reported a large burden of disease among patients receiving care in Ministry of Health facilities (Ministry of Health Malaysia, 2023). Many patients with diabetes also suffered from hypertension and dyslipidemia (Ministry of Health Malaysia, 2023; Institute for Public Health, 2024).

Various mechanisms are associated with the development of T2DM. Earlier studies placed insulin resistance in muscle and adipose tissue, increased glucose production by the liver, and β -cell failure as core mechanisms in the pathogenesis of T2DM (Galicia-Garcia et al., 2020). Recent studies suggested that fat tissue changes, including fat accumulation in organs, inflammation, malfunction of incretin hormones, and disturbed cell signalling, may also be involved (Lu et al., 2024).

T2DM causes serious health problems. It damages small blood vessels, causing complications in the eyes, kidneys, and nerves (WHO, 2024). Larger vessels may also be affected, resulting in heart disease, stroke, and poor circulation in the arms and legs (WHO, 2024). In 2021 alone, there were about 1.6 million deaths from diabetes worldwide, and approximately half occurred in individuals under 70 years of age (WHO, 2024).

Evidence shows that lifestyle changes can help to prevent T2DM. Weight loss from diets focusing on improved fat quality, increased fibre, and increased intake of whole grains, fruits, and vegetables, along with regular physical activity, can significantly decrease the risk (Uusitupa et al., 2019). To be effective long-term, weight loss must be sustained along with lifestyle changes (Uusitupa et al., 2019).

Current guidelines for the management of diabetes focus on individualised blood glucose targets along with control of cardiovascular risk factors (Ministry of Health Malaysia et al., 2020; ADA, 2024). The best outcomes can be achieved when a team of health professionals works together to support patients (Andersen et al., 2023). Coordinated care is important in preventing complications and improving the quality of life in patients with T2DM (Andersen et al., 2023).

2.2 RELEVANCE OF ANTHROPOMETRIC INDICATORS AND THEIR RELATIONSHIP WITH TYPE 2 DIABETES MELLITUS

BMI is one of the most common tools for classifying weight status and is generally associated with the risk of developing T2DM (Abdullah et al., 2010). Studies reported that obesity was associated with about a sevenfold increase in diabetes risk, while being overweight was associated with about a threefold increase compared with normal-weight adults (Abdullah et al., 2010). Another meta-analysis also showed that being overweight or obese increased the risk of prediabetes and T2DM, whereas underweight individuals may show a small protective trend (Yu et al., 2022). However, the relationship was complicated by changes in BMI over time. In longitudinal studies, people whose BMI increased gradually over several years developed T2DM more often than those who maintained a stable and lower BMI (Hassanloo et al., 2024). For people already living with T2DM, a higher BMI was generally associated with poorer glycaemic control (Deng et al., 2025). Nevertheless, a meta-analysis of placebo-controlled clinical trials found that although baseline BMI increased across study populations, baseline HbA1c levels did not consistently increase in parallel (Hu et al., 2023). This suggested that the relationship between BMI and glycaemic control may vary across different populations and clinical settings (Hu et al., 2023).

Waist circumference provides another perspective. Instead of reflecting overall body size, it indicates how fat is stored around the abdomen. This is important because visceral fat is more metabolically active and linked with insulin resistance (Jayedi et al., 2022). Several cohort studies have shown that waist circumference is an independent predictor of T2DM, apart from BMI (Feller et al., 2010). Some studies reported that waist circumference performed better than BMI in predicting diabetes in adults (Fan et al., 2020). The suggested

cut-offs varied according to sex and ethnicity because people accumulate fat differently (Friedl, 2009).

Body fat percentage gives a more direct estimate of total fat and identifies individuals who appear healthy by BMI but actually carry excess fat (Li et al., 2022). This condition, known as “normal-weight obesity”, has also been associated with an increased risk of diabetes (Li et al., 2022). In many studies, total and visceral fat have been observed to be higher in people with T2DM than in those without (Alfadhli et al., 2025). Among Chinese adults, a study reported that body fat percentage and visceral fat area predicted T2DM independently of age and sex (Chen et al., 2020). Recent cohort findings and meta-analyses also suggested that even small increases in body fat percentage may be associated with measurable increases in diabetes risk (Pan et al., 2025).

These indicators have been compared in several studies, but their patterns differ from one study to another. One such analysis revealed that all anthropometric indicators were associated with T2DM (Bai et al., 2022). However, waist circumference showed the strongest association in men, while BMI was more prominent in women (Bai et al., 2022). Another study found that body fat percentage showed the strongest association with T2DM (Han et al., 2019). The highest body fat group had an odds ratio of about 11.1, followed by waist circumference at 8.7 and BMI at 6.5 (Han et al., 2019).

In practice, it is better to use multiple indicators in combination, such as BMI together with waist circumference or body fat percentage, to identify individuals at higher risk of T2DM (Jayedi et al., 2022). Studies among people with T2DM have also shown that adiposity is not only a risk factor but also a potential target for treatment, as reductions in

body weight and central fat have been associated with improvements in glycaemic control (Boye et al., 2021).

2.3 ASSOCIATION BETWEEN BODY MASS INDEX AND GLYCAEMIC CONTROL

BMI is commonly used to assess nutritional status. It is also used in the assessment of health risks in patients with T2DM (Deng et al., 2025). Higher BMI usually means more fat in the body, which can make insulin resistance worse and affect glycaemic control (Deng et al., 2025).

Various studies have reported that T2DM patients with higher BMI have poorer glycaemic control. In fact, one study found a significant association between BMI and HbA1c levels in obese diabetic patients (Rahman et al., 2024). Another study showed that obese patients had higher HbA1c levels compared with overweight or normal-weight individuals (Sisodia et al., 2019). Similar findings have also been reported in Malaysia, where BMI was significantly associated with glycaemic control among patients with T2DM (Mahmood et al., 2016; Hassan et al., 2021). These findings suggest that weight management plays an important role in achieving better glycaemic outcomes in T2DM patients.

However, these results were inconsistent. Some studies showed that BMI predicted HbA1c levels in people without diabetes, but the link was weaker or less clear in people with diabetes (Lin, 2024). In one study conducted on hospitalised T2DM patients, no substantial association between BMI and glycaemic control was found (Paul et al., 2016). This study reported that age was more strongly related to glycaemic control than BMI or other measures

(Paul et al., 2016). Consistent with these findings, some Malaysian studies have also reported no significant association between BMI and glycaemic control among patients with T2DM (Abdullah et al., 2019; Ahmad et al., 2026).

Some research mentioned an “obesity paradox”, which meant that overweight or mildly obese patients sometimes had similar or slightly better outcomes compared to those with lower BMI (Dramé et al., 2023). This made the relationship between BMI and glycaemic control more complex. The mixed results may be explained by the limitations of BMI, as it cannot differentiate between fat and muscle or indicate fat distribution (Hu et al., 2023).

Overall, higher BMI was often linked to poorer glycaemic control in T2DM patients (Sisodia et al., 2019; Rahman et al., 2024). However, findings were inconsistent. This indicated that BMI alone may not be a sufficient predictor of glycaemic outcomes. Therefore, although BMI remains a simple and practical tool, it should be used together with other measures to better assess body fat and its impact on glycaemic control (Sweatt et al., 2024).

2.4 ASSOCIATION BETWEEN WAIST CIRCUMFERENCE AND GLYCAEMIC CONTROL

Waist circumference is a simple measurement that reflects central adiposity and visceral fat. Many researchers believe that waist circumference may reflect glucose metabolism better than general measures like BMI (Zhen et al., 2022). Hence, it may be useful in reflecting glycaemic control among people with T2DM (Zhen et al., 2022).

Several studies have shown that increased waist circumference is linked to poor glycaemic control among patients with T2DM. A study in a large Chinese sample found that bigger waists generally meant higher HbA1c levels (Zhen et al., 2022). Another study from Bangladesh also reported that patients who had poor glycaemic control tended to have higher waist measurements compared to those with better control (Sultana et al., 2021). Several studies in Malaysia have also reported a significant association between waist circumference and glycaemic control among patients with T2DM (Tharek et al., 2018; Hassan et al., 2021).

However, findings were not entirely consistent across all studies. Factors such as age, sex, and ethnicity can alter how waist circumference relates to glycaemic control (Oumer et al., 2022). One study compared waist circumference with waist-to-hip and waist-to-height ratios and reported that each of these measures predicted glycaemic control differently based on these factors (Oumer et al., 2022). Another study pointed out that even physical factors, such as handgrip strength, could influence this relationship in Japanese patients (Nakanishi et al., 2024).

The relationship between waist circumference and glycaemic control is biologically explainable. Excess abdominal fat releases more free fatty acids and inflammatory mediators (Shang et al., 2024). This reduces insulin sensitivity and makes glucose regulation more difficult (Shang et al., 2024). In addition, visceral fat is metabolically active (Sultana et al., 2021). It influences the secretion of key molecules such as leptin and adiponectin, which play important roles in insulin resistance and the development of diabetes (Sultana et al., 2021). One recent study found that visceral fat area was associated with HbA1c levels, with an inverted U-shaped relationship observed among T2DM patients (Luo et al., 2023).

In conclusion, most studies suggested that higher waist circumference was associated with poorer glycaemic control among people with T2DM (Sultana et al., 2021; Zhen et al., 2022). However, the strength and direction of this relationship may vary across populations and various factors. Therefore, researchers and clinicians should consider waist circumference together with other measurements when assessing glycaemic control and planning management strategies (Oumer et al., 2022).

2.5 ASSOCIATION BETWEEN BODY FAT PERCENTAGE AND GLYCAEMIC CONTROL

Body fat percentage is a direct way of quantifying adiposity. It reflects the proportion of fat in the body and may provide more meaningful information than body weight or BMI alone (Potter et al., 2025). It has been suggested that the overall amount of fat and its distribution may influence glucose metabolism and long-term glycaemic markers among people with T2DM (Jo et al., 2018).

Several studies have explored this. For example, cross-sectional studies found that adults with higher body fat percentages tended to have higher HbA1c levels, especially in men (Bower et al., 2017). Another study utilising continuous glucose monitoring showed that individuals with more body fat spent less time in the target glucose range (Ruan et al., 2021). This suggested poorer day-to-day glycaemic control (Ruan et al., 2021). The authors concluded that decreasing body fat might be an important target for improving glycaemic control in T2DM patients, as patients with high adiposity could be less responsive to intensive insulin treatment (Ruan et al., 2021).

However, not all findings pointed in the same direction. A recent study reported that changes in HbA1c levels were negatively associated with muscle mass and bone mineral content, but not with body fat percentage (Nomura et al., 2024). Another study also reported a nonlinear relationship between body fat percentage and HbA1c levels (Li et al., 2022). They reported observing a positive association when HbA1c levels were below 7%, but an opposite trend when levels were above 7% (Li et al., 2022). This may be because patients with poor glycaemic control may lose fat due to increased fat breakdown, so the relationship between body fat percentage and HbA1c levels can vary depending on glycaemic control (Li et al., 2022).

One possible explanation is that excess fat has an impact on muscles and glucose metabolism. A recent study illustrated that the greater the percentage of body fat, the higher the risk for T2DM patients to develop sarcopenia (Hou et al., 2024). Sarcopenia refers to the loss of skeletal muscle mass and function (Hou et al., 2024). As skeletal muscle is the major tissue for the uptake of glucose under insulin stimulation, loss of muscle strength potentially impairs overall glycaemic control (Merz et al., 2020). Moreover, differences in body fat assessment methods, such as bioelectrical impedance analysis (BIA), dual-energy X-ray absorptiometry (DXA), and computed tomography (CT), may explain inconsistent findings across studies (Castillo et al., 2024).

Overall, many studies suggested that a higher percentage of body fat was related to poorer glycaemic control in people with T2DM (Bower et al., 2017; Ruan et al., 2021). However, the results were not universal. Future studies should continue to explore the mechanisms linking body fat percentage and glucose regulation to clarify this relationship.

CHAPTER 3: METHODOLOGY

3.1 STUDY DESIGN

This study was a cross-sectional study conducted among patients with T2DM at HPUSM to examine the association of BMI, waist circumference, and body fat percentage with glycaemic control. The researcher adopted a cross-sectional study design because it is an observational approach that allows the collection of data on multiple variables at a single point in time. This design enabled the researcher to assess the relationships between anthropometric indicators and glycaemic control efficiently, within a limited time frame and with minimal resources.

3.2 STUDY AREA

The study was conducted at HPUSM, Kubang Kerian, Kelantan. This hospital serves a high volume of patients, including those diagnosed with T2DM. Data collection was carried out across five outpatient clinics, namely Klinik Pakar Perubatan (KPP), Klinik Rawatan Keluarga (KRG), Outpatient Dietetics Clinic, Staff Clinic, and Diabetes Centre.

3.3 STUDY POPULATION

Reference Population

Adults with T2DM receiving outpatient care at HPUSM, Kubang Kerian, Kelantan.

Target Population

Adults with T2DM attending the selected outpatient clinics, including KPP, KRK, Outpatient Dietetics Clinic, Staff Clinic, and Diabetes Centre, at HPUSM, Kubang Kerian, Kelantan.

Source Population

Adults with T2DM attending the selected outpatient clinics at HPUSM, Kubang Kerian, Kelantan, during the study recruitment period.

Sampling Frame

Clinic attendance or appointment lists of adults with T2DM attending the selected outpatient clinics at HPUSM, Kubang Kerian, Kelantan; however, participants were recruited through direct approach in the clinic waiting areas using convenience sampling.

3.4 SUBJECT CRITERIA**3.4.1 INCLUSION CRITERIA**

1. Adults aged 19 years and above.
2. Registered outpatients at HPUSM.
3. Clinically confirmed diagnosis of T2DM.
4. Availability of HbA1c laboratory data within the past 3 to 6 months in the patient's medical record.
5. Physically able to stand unassisted for anthropometric and body composition measurements.

3.4.2 EXCLUSION CRITERIA

1. Individuals diagnosed with prediabetes, type 1 diabetes mellitus (T1DM), or gestational diabetes mellitus.
2. Pregnant or lactating women.
3. Patients who are disabled, critically ill, or have psychiatric illnesses that limit participation.
4. Individuals with implanted electronic medical devices or metallic implants that contraindicate BIA measurement.

3.5 SAMPLE SIZE CALCULATION

Sample size was calculated using G*Power software (version 3.1). As most local studies that conducted correlation analyses were based on specific subgroups and did not report effect sizes (correlation coefficients) for a general T2DM population, values were obtained from studies conducted in other Asian countries with similar populations.

3.5.1 BASED ON BODY MASS INDEX AND GLYCAEMIC CONTROL (HbA1c)

A previous study conducted in China reported a significant positive correlation between BMI and HbA1c ($r = 0.45$, $p < 0.001$) (Deng et al., 2025). Therefore, this study applied an effect size of $r = 0.45$. The alpha error probability (α) was set at 0.05, and the power of the study ($1 - \beta$) was set at 0.80.

Test family: Exact

Statistical test: Correlation: Bivariate normal model

Type of power analysis: A priori

Effect size (correlation coefficient), $r = 0.45$

Alpha error probability, $\alpha = 0.05$

Power (1 – Beta error probability), $1 - \beta = 0.80$

Total sample size = 36

In clinical research, the dropout or noncompliance rate is typically around 10% (Althubaiti, 2022). To account for this, the sample size was adjusted by dividing by (1 – dropout rate) (Althubaiti, 2022).

$$\text{Adjusted sample size (accounting for 10\% dropout rate)} = \frac{36}{1-0.10} = 40$$

3.5.2 BASED ON WAIST CIRCUMFERENCE AND GLYCAEMIC CONTROL (HbA1c)

A previous study conducted in Indonesia reported a significant positive correlation between waist circumference and HbA1c ($r = 0.60$, $p = 0.001$) (Maulina et al., 2024). Therefore, this study applied an effect size of $r = 0.60$. The alpha error probability (α) was set at 0.05, and the power of the study ($1 - \beta$) was set at 0.80.

Test family: Exact

Statistical test: Correlation: Bivariate normal model

Type of power analysis: A priori

Effect size (correlation coefficient), $r = 0.60$

Alpha error probability, $\alpha = 0.05$

Power (1 – Beta error probability), $1 - \beta = 0.80$

Total sample size = 19

Adjusted sample size (accounting for 10% dropout rate) = $\frac{19}{1-0.10} \approx 22$

3.5.3 BASED ON BODY FAT PERCENTAGE AND GLYCAEMIC CONTROL (HbA1c)

According to Cohen (1988), effect sizes for correlation are classified as small ($r = 0.10$), medium ($r = 0.30$), and large ($r = 0.50$). Due to the lack of precise effect size data for the target population, a medium effect size of $r = 0.30$ was used, providing a balance between study feasibility and statistical efficiency. The alpha error probability (α) was set at 0.05, and the power of the study ($1 - \beta$) was set at 0.80.

Test family: Exact

Statistical test: Correlation: Bivariate normal model

Type of power analysis: A priori

Effect size (correlation coefficient), $r = 0.30$

Alpha error probability, $\alpha = 0.05$

Power (1 – Beta error probability), $1 - \beta = 0.80$

Total sample size = 84

Adjusted sample size (accounting for 10% dropout rate) = $\frac{84}{1-0.10} \approx 94$

3.5.4 FINAL SAMPLE SIZE DETERMINATION

The calculated sample sizes for the three specific objectives ranged from 22 to 94. To ensure adequate statistical power for all analyses, the largest calculated sample size of 94 was selected. Therefore, a total of 94 participants were recruited for this study.

3.6 SAMPLING METHOD AND SUBJECT RECRUITMENT

The samples in this study were recruited using a convenience sampling method, which is a non-probability sampling technique. Participants were selected based on their availability and willingness to participate. This method enabled the researcher to efficiently approach and recruit eligible patients in a real clinical setting.

A total of 94 participants were recruited from outpatients attending KPP, KRK, Outpatient Dietetics Clinic, Staff Clinic, and Diabetes Centre at HPUSM. The researcher approached patients directly in the clinic waiting areas and screened them for eligibility based on the inclusion and exclusion criteria. During this process, patients were briefly informed about the study, and their eligibility was assessed through simple screening questions. A study poster was also displayed in the clinics to allow interested patients to contact the research team for screening, as shown in Appendix D.

3.7 RESEARCH INSTRUMENTS

The research instrument, a structured data collection form, used in this study was developed in both English and Malay to collect demographic and socioeconomic information, clinical information, as well as anthropometric and laboratory measurements from participants. The instrument consisted of three parts: Part A, Part B, and Part C, as shown in Appendix A.

3.7.1 PART A: DEMOGRAPHIC AND SOCIOECONOMIC INFORMATION

This section collected participants' background information, including age, gender, ethnicity, education level, marital status, employment status, and monthly household income.

3.7.2 PART B: CLINICAL INFORMATION

This section collected data regarding the duration of T2DM diagnosis, treatment type, and the presence of comorbidities such as hypertension, hyperlipidaemia, cardiovascular disease, chronic kidney disease, chronic liver disease, and cancer.

3.7.3 PART C: ANTHROPOMETRIC AND LABORATORY MEASUREMENTS

This section included the measurements of height, weight, waist circumference, and body fat percentage. For the assessment of glycaemic control, the most recent HbA1c values within the past 3 to 6 months were retrieved from participants' medical records.