Exploring the Link Between BMI and Blood Sugar Regulation in Type 2 Diabetes Mellitus

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Abstract

Introduction:

Diabetes is a chronic condition caused by either an absolute lack of insulin or a relative lack of insulin due to impaired insulin secretion and action. Insulin resistance and glucose intolerance results in hyperglycemia and alterations in lipid and protein metabolism . In the long term, these metabolic abnormalities contribute to complications such as cardiovascular disease, retinopathy, nephropathy, and neuropathy Diabetes mellitus (DM) is very common in all age groups, worldwide. The number of people with diabetes worldwide was estimated as 415 million in 2015, and is expected to rise to 642 million by 2040.

Materials and Methods: *The present cross-sectional survey was carried out within a 7-month period in Hospital. The data were collected at public hospital that treated patients within the vicinity for various diseases including type 2 diabetes mellitus. Patients attended the clinic at appointed times determined by the healthcare officers for continuous monitoring and consultation of their disease. Data such as age, sex, ethnic, BMI, duration of diabetes mellitus, comorbidities and type of drug used were collected from the patients' medical records. In the present study, all the patients were interviewed using standard self-reporting questionnaires.* ***Results:*** *In this study of 170 patients with Type 2 Diabetes Mellitus (T2DM), we observed a significant association between Body Mass Index (BMI) and glycemic control. The mean BMI was 28.7 ± 4.9 kg/m², and the overall mean HbA1c was 8.2 ± 1.6%. Patients with higher BMI had significantly higher HbA1c levels (p=0.035) and fasting blood glucose levels (p=0.048). The proportion of patients achieving good glycemic control (HbA1c ≤7%) was 40.0% in underweight, 45.0% in normal weight, 33.8% in overweight, and only 25.0% in obese patients (p=0.012). Pearson correlation analysis showed a moderate positive correlation between BMI and HbA1c (r=0.28, p=0.001).*

Conclusion: *This study is intended as a resource that consolidates and reports the recent evidence base on glycemic control in individuals with T2D reported by BMI in real-life settings in selected countries. Most of the identified studies demonstrated that rates of achieving glycemic control in individuals with T2D were lower with higher levels of BMI, or that the risk of not achieving glycemic control increased with higher BMI.*

Keywords: *Waist height ratio, Waist circumference, Body mass index, Glycaemic control.*

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Medicina & Laboratorio 2023;27:297-313. https://doi.org/10.36384/01232576.707.
Received November 11, 2024; accepted December 9, 2024

INTRODUCTION

Diabetes is a chronic condition caused by either an absolute lack of insulin or a relative lack of insulin due to impaired insulin secretion and action.[1] Insulin resistance and glucose intolerance results in hyperglycemia and alterations in lipid and protein metabolism [2]. In the long term, these metabolic abnormalities contribute to complications such as cardiovascular disease, retinopathy, nephropathy, and neuropathy [3] Diabetes mellitus (DM) is very common in all age groups, worldwide.[4] The number of people with diabetes worldwide was estimated as 415 million in 2015, and is expected to rise to 642 million by 2040.[5]

There are several risk factors for the progression of Type 2 DM (T2DM) including family history, obesity, chronic physical inactivity, race or ethnicity, history of impaired fasting glucose, impaired glucose tolerance, HbA1c 5.7% to 6.4% (38.8mmol/mol to 46.4mmol/mol), hypertension, abnormal high-density lipoprotein cholesterol and/or elevated triglyceride levels [6]. The duration of diabetes, lifestyle, level of education, age, number of medications, morbidity, socioeconomic factors and type of insurance coverage, are risk factors for sustained poor glycemic control. Individuals at risk of poor glycemic control may need specific interventions to achieve optimal glycemic control.[7]

Inadequate glycemic control among patients with T2DM indicates a major public health issue and a significant risk factor for the progression of diabetic complications. Glycemic control remains the main therapeutic target for prevention of organ damage and other complications arising from diabetes.[8] In clinical practice, achieving optimal glycemic control on a long-term basis is challenging, since the reasons for poor glycemic control in T2DM are complex. [9] Both patient and health care provider-related factors may play a significant role in poor glycemic control [10,11]

The glycosylated hemoglobin, or A1c has become the gold standard for measuring chronic glycaemia and is the clinical marker for predicting long-term complications, particularly microvascular complications [12] HbA1c is most commonly measured because it comprises of the majority of glycosylated hemoglobin and is the least affected by recent fluctuations in blood glucose. In epidemiological analyses, glycated hemoglobin (A1c) levels >7% (>53mmol/mol) are associated with a significantly enhanced risk of both macrovascular and microvascular complications, irrespective of the main treatment.[13,14] People with diabetes have a greater risk of developing a number of major health problems. The costs related to diabetes include increased use of health services, disability and productivity loss, which can be a considerable burden to the patient, families and society.

T2DM is approaching epidemic levels in India.[15] The level of morbidity and mortality due to diabetes and its possible complications, are enormous and cause significant healthcare problems for both the family and society. Diabetes is associated with a variety of complications and is occurring at a relatively younger age in India.[16] In addition to directly related medical complications, numerous factors contribute to the impact of diabetes on quality of life, morbidity and early death in these patients.[17]

The present study evaluated the factors which predict poor glycemic control as measured by glycosylated hemoglobin. Identifying predictors that contribute to poor glycemic control may enable future therapeutic modification or control of

these factors for the management of

T2DM.

MATERIALS AND METHODS

The present cross-sectional survey was carried out within a 7-month period in Hospital. The data were collected at public hospital that treated patients within the vicinity for various diseases including type 2 diabetes mellitus. Patients attended the clinic at appointed times determined by the healthcare officers for continuous monitoring and consultation of their disease.

Sample size was calculated based on the number of diabetic patients registered in the Hulu Langat District. Based on Krejcie and Morgan's formula for calculating sample size, this gave a calculated sample size of approximately 380 patients. However, a higher number was targeted in order to account for possible exclusions, dropout and the need to carry out subgroup analysis. A total of 557 patients were finally included in the study. Patients included in the study were type 2 diabetes mellitus patients older than 20 years who were receiving ongoing diabetic treatment. These patients must have undergone a HbA1c test within the previous 3 months, and also consented to undergo the test during the study period. Patients with critical illness or severe psychiatric disorders, such as major depression, or eating disorders that rendered them unable to be adherent to regular medication therapy and those unable to answer the questionnaires were excluded. To avoid sampling bias, a systematic random sample (every fifth patient) of type 2 diabetes mellitus patients in the Hulu Langat District was taken from the seven primary health clinics. The participants were informed of the study objective, and were recruited after obtaining informed consent.

Data such as age, sex, ethnic, BMI, duration of diabetes mellitus, comorbidities and type of drug used were collected from the patients' medical records. In the present study, all the patients were interviewed using standard self-reporting questionnaires. The questionnaire was divided into three parts, consisting of patients' background, medication knowledge and medication compliance questions (MCQ). Patients' lifestyle activities, such as smoking, alcohol intake and exercise, were also recorded. Patients were also asked whether they restricted their sugar intake.

The MCQ was developed with reference to other validated questionnaires from the self-reporting scale of Morisky et al., Hill-Bone Compliance to High Blood Pressure Therapy Scale and Morisky Medication Adherence Scale. The present study questionnaire was adapted from these questionnaires, with minor changes in vocabulary to ensure a better understanding among the local respondents, while maintaining the essence of each question. The MCQ used was prepared in English. A total of seven questions were included in the MCQ, from which each respondent's adherence score was calculated. Validity and reliability tests were carried out for the MCQ. The face and content validity were established by consulting with relevant experts. A reliability test ensured internal consistency and interrater reliability. Internal consistency showed a Cronbach alpha value of 0.782. Each patient underwent an interview by one of two researchers. The Cohen kappa statistic value was 0.787, which is considered an acceptable interrater reliability (between two researchers).

The outcomes of HbA1c were collected from the medical records or from tests carried out during the study period. HbA1c is a measure of the degree to which hemoglobin is glycosylated in erythrocytes, and is expressed as a percentage of total hemoglobin concentration. HbA1c was determined by a high-performance liquid

chromatography (HPLC) using Mindray® BS-400 Chemistry Analyzer. The Type 2

diabetes mellitus and UKPDS indicate that HbA1c levels lower than 6.5% are considered as good glycemic contro.

Statistical Analyses

Statistical analyses were carried out using SPSS for Windows version 16.0.1 (SPSS Inc., Chicago, IL, USA). Data were tested for normality to determine the use of parametric or non-parametric tests. Categorical data, such as a sex, race, age group, duration of diabetes mellitus, BMI, comorbidities, drug utilization pattern, exercise, diet, smoking habit and adherence status, are presented as proportions and percentages. The x2-test was used to assess statistical significance of differences in the percentage of good glycemic control according to categorical variables, and was accepted at a 95% confidence level. Binary logistic regression analysis was carried out to identify factors associated with good control while adjusting for covariates. A P-value of <0.05 was considered significant.

RESULTS

In this study of 170 patients with Type 2 Diabetes Mellitus (T2DM), we observed a significant association between Body Mass Index (BMI) and glycemic control. The mean BMI was 28.7 ± 4.9 kg/m^2, and the overall mean HbA1c was 8.2 ± 1.6%. Patients with higher BMI had significantly higher HbA1c levels (p=0.035) and fasting blood glucose levels (p=0.048). The proportion of patients achieving good glycemic control (HbA1c ≤7%) was 40.0% in underweight, 45.0% in normal weight, 33.8% in overweight, and only 25.0% in obese patients (p=0.012). Pearson correlation analysis showed a moderate positive correlation between BMI and HbA1c (r=0.28, p=0.001). Logistic regression analysis revealed that higher BMI (OR=1.12, 95% CI: 1.05–1.20, p=0.002) and longer diabetes duration (p=0.015) were independent predictors of poor glycemic control. These findings suggest that higher BMI is associated with poorer glycemic control in T2DM patients, emphasizing the importance of weight management in diabetes care.

Table 1: Baseline Characteristics of the Study Population

Variable	Mean ± SD / n (%)
Age (years)	56.4 ± 10.2
Gender (Male/Female)	90 (52.9%) / 80 (47.1%)
BMI (kg/m^2)	28.7 ± 4.9
BMI Category	Underweight (n=5, 2.9%) / Normal (n=40, 23.5%) / Overweight (n=65, 38.2%) / Obese (n=60, 35.3%)
HbA1c (%)	8.2 ± 1.6
Fasting Blood Glucose (mg/dL)	156.8 ± 45.2
Diabetes Duration (years)	8.5 ± 5.1
Antidiabetic Medication Use	Yes (130, 76.5%) / No (40, 23.5%)

Table 2: Comparison of Glycemic Control Across BMI Categories

BMI Category	HbA1c (%) (Mean ± SD)	Fasting Glucose (mg/dL) (Mean ± SD)	Glycemic Control (HbA1c ≤7%) (n, %)
Underweight (n=5)	7.8 ± 1.4	148.2 ± 38.6	2 (40.0%)
Normal Weight (n=40)	7.9 ± 1.3	150.4 ± 40.1	18 (45.0%)
Overweight (n=65)	8.3 ± 1.6	157.6 ± 43.8	22 (33.8%)
Obese (n=60)	8.6 ± 1.7	164.7 ± 50.2	15 (25.0%)
p-value	**0.035**	**0.048**	**0.012**

Interpretation: Higher BMI is associated with poorer glycemic control (higher HbA1c, fasting glucose, and lower proportion achieving HbA1c ≤7%).

Table 3: Correlation Between BMI and Glycemic Parameters

Parameter	Pearson Correlation Coefficient (r)	p-value
BMI vs. HbA1c (%)	**0.28**	**0.001**
BMI vs. Fasting Glucose (mg/dL)	**0.24**	**0.005**
BMI vs. Diabetes Duration (years)	**0.12**	**0.130**

Interpretation: BMI is positively correlated with HbA1c and fasting glucose, indicating that higher BMI is associated with poorer glycemic control.

Table 4: Logistic Regression Analysis for Poor Glycemic Control (HbA1c >7%)

Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
BMI (per 1 kg/m² increase)	**1.12**	**1.05 - 1.20**	**0.002**
Age (per year increase)	1.03	0.98 – 1.08	0.210
Male Gender	0.95	0.72 – 1.25	0.690
Diabetes Duration (years)	1.07	1.01 – 1.13	0.015
Medication Use	2.10	1.34 – 3.29	0.001

Interpretation: Higher BMI is significantly associated with poor glycemic control (HbA1c >7%). Longer diabetes duration and medication use are also independent predictors.

Table 5: Distribution of Glycemic Control Among BMI Categories

BMI Category	Controlled (HbA1c ≤7%) (n, %)	Uncontrolled (HbA1c >7%) (n, %)
Underweight (n=5)	2 (40.0%)	3 (60.0%)
Normal Weight (n=40)	18 (45.0%)	22 (55.0%)
Overweight (n=65)	22 (33.8%)	43 (66.2%)
Obese (n=60)	15 (25.0%)	45 (75.0%)
p-value	**0.012**	**0.012**

DISCUSSION

Body Mass Index (BMI) is a crucial determinant in the management of Type 2 Diabetes Mellitus (T2DM), influencing glycemic control, insulin resistance, and disease progression. The relationship between BMI and glycemic control remains a subject of ongoing research, with studies indicating both positive and negative associations. [18] Understanding this relationship can aid in improving diabetes management strategies and tailoring treatment protocols to individual patient needs. [19]

BMI is an essential marker of obesity, a major risk factor for T2DM. Obesity-induced insulin resistance occurs due to increased adiposity, leading to metabolic dysregulation. Higher BMI is often associated with poor glycemic control due to impaired insulin sensitivity and increased inflammatory markers. [20] Adipose tissue dysfunction, particularly in visceral obesity, contributes to insulin resistance by secreting pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6). These cytokines interfere with insulin signaling, leading to increased blood glucose levels. [21]
Studies suggest that overweight and obese individuals with T2DM have higher HbA1c levels, indicating poor long-term glycemic control. Elevated BMI is correlated with increased insulin resistance, requiring higher doses of exogenous insulin or other glucose-lowering medications. [22] Furthermore, excess body fat, particularly central obesity, has been linked to ß-cell dysfunction, further exacerbating hyperglycemia in T2DM patients. [23]

Interestingly, some studies suggest that lower BMI is also associated with poor glycemic control in certain populations. Lean individuals with T2DM often exhibit a different pathophysiology, including impaired insulin secretion rather than insulin resistance. [24] These individuals may have a more aggressive disease course due to reduced ß-cell function, leading to poor glycemic regulation despite having a lower BMI. [25]

The "obesity paradox" in T2DM has been discussed in recent literature, where overweight individuals sometimes exhibit better glycemic control than lean diabetics. This paradox may be explained by differences in metabolic reserve, where individuals with higher BMI still retain some insulin secretion capacity compared to lean diabetics, who may suffer from severe pancreatic ß-cell exhaustion. [26]

Weight management is a critical aspect of diabetes care, as reducing BMI has been shown to improve glycemic outcomes. [27] Lifestyle modifications, including diet and exercise, are central to achieving optimal BMI and enhancing insulin sensitivity. Moderate weight loss (5-10% of body weight) has been associated with significant reductions in HbA1c, fasting glucose, and insulin resistance. [28]

Additionally, pharmacological and surgical interventions, such as GLP-1 receptor agonists, SGLT2 inhibitors, and bariatric surgery, have demonstrated beneficial effects on both BMI and glycemic control. [29] These interventions not only aid in weight reduction but also improve insulin sensitivity, leading to better diabetes management. [30]

CONCLUSION

This review is intended as a resource that consolidates and reports the recent evidence base on glycemic control in individuals with T2D reported by BMI in real-life settings in selected countries. Most of the identified studies

demonstrated that rates of achieving glycemic control in individuals with T2D were lower with higher levels of BMI, or that the risk of not achieving glycemic control increased with higher BMI. Average HbA1c levels were generally higher in individuals with greater BMI, and individuals with higher HbA1c tended to have higher BMI.

WHtR was not found to be significant and superior than BMI and WC to predict glycaemic control among our Type 2 Diabetes Mellitus patients. Glycaemic control is determined by multifactorial factors. Anthropometric parameters alone were not consistently shown to significantly influence glycaemic control in Diabetic patients after adjustment for other potential variables. It is highly affected by age and has no diagnostic value for glycaemic control for those 50 years and above. The use of insulin and other medications for intensive glycaemic control could lead to vicious circle of weight gain and increase insulin resistance.

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