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Original Article

DOI: 10.53389/RJAHS.2025040105

Exploring the Impact of Combined Body Mass Index and Glycated Haemoglobin (HbA1c) Levels on Pre-Diabetes Risk

Shanzah Adnan, Imran Tipu*

Department of Life Sciences, School of Science, University of Management and Technology, Lahore.

Author`s Contribution

[SA] Conception and design, [SA] Collection and assembly of data, [SA, IT] Analysis and interpretation of the data, Statistical expertise, [IT] Final approval and guarantor of the article

Article Info.

Received: Feb 02, 2025
Acceptance: March 25, 2025

Conflict of Interest: None

Funding Sources: None

Address of Correspondence

Imran Tipu*
Department of Life Sciences, School of Science, University of Management and Technology, Lahore, 54770, Pakistan
imran.tipu@umt.edu.pk

A B S T R A C T

Background: Prediabetes, a global health concern with its trending prevalence intensified the need of early and effective interventions. It's a medical condition, recognized by elevated blood glucose but not sufficiently high to be defined as Type 2 Diabetes Mellitus. Key factors for prediabetes diagnosis included, HbA1c (a biomarker) which shows a comprehensive picture of glycaemic range from past 2 to 3 months with values from 5.7% to 6.4% indicating prediabetes. Body Mass Index (BMI), depicting adiposity in body leading to insulin sensitivity and impaired glucose metabolism, classifying participants into healthy, overweight and obese categories.

Objective: The primary objective was to explore the effect of BMI and HbA1c levels in participants to assess pre-diabetes risk.

Methodology: A quantitative, cross-sectional study was conducted between February 2023 and August 2024. The study population comprised university students aged 20–25 years, selected through stratified random sampling based on inclusion/exclusion criteria (excluding those with existing medical conditions). A total of 110 participants were enrolled following informed consent. BMI was calculated using standard anthropometric methods. HbA1c was measured via blood sampling using standardized laboratory protocols, while RBG levels were assessed using a handheld glucometer. Data were statistically analyzed using SPSS software.

Results: Among the 110 participants, 46 were male and 64 were female. BMI classification revealed 38.2% were within a healthy range (n=42), 41.8% overweight (n=46), and 20% obese (n=22). Based on HbA1c, 58.2% (n=64) had normal levels, while 41.8% (n=46) were in the prediabetic range. RBG results showed 59.1% (n=65) with normal glucose levels and 40.9% (n=45) falling within the prediabetic range. Pearson's correlation analysis revealed a significant positive correlation between BMI and HbA1c ($r = 0.46$, $p < 0.001$), indicating elevated BMI is independently associated with prediabetes risk. In contrast, the correlation between HbA1c and RBG was non-significant ($r = 0.182$, $p > 0.05$), suggesting that elevated RBG may not directly influence HbA1c levels.

Conclusion: This study highlights the relevance of timely evaluation of Body Mass Index and Glycated Haemoglobin level to evaluate pre-diabetes for prompt interventions.

Keywords: Body Mass Index, Glycated Haemoglobin, random blood glucose level, pre-diabetes, obesity, Type 2 Diabetes Mellitus.

Introduction

Pre-diabetes was the reflection of health worldwide.[1] It had a significant impact causing public health challenge because of the lifestyle modifications.[2] Pre-diabetes prevalence showed a prominent rising trend from year 2020 to 2023.[3] In 2021, IDF Diabetes Atlas 10 edition, estimated that 537 million people globally from age 20-79 years old who were suffering with diabetes mellitus, were expected to increase up to 754 million by the year 2045.[4] Worldwide epidemiological survey had unveiled rise in the incidence of pre-diabetes in different demographical areas.[5,6] As reported by International Diabetes Federation (IDF), for the South East Asian (SEA) countries, the estimated prevalence of diabetes was 8.7% by the year 2021 and was expected to increase up to 11.3% by the year 2045.[7,8] So, the basis of conducting this study was the persistent need

to comprehensively evaluate the risk factors which contributed in the onset of pre-diabetes condition. As there is a global increase in incidence and prevalence of pre-diabetes,[9–11] therefore it was crucial to explore the factors for early detection and prevention of this condition. Previous studies had shown the incidence of pre-diabetes,[12] population-based studies on pre-diabetes,[13,14] its intervention and prevention[15,16] and studies on individual risk factors acting as diagnostic marker,[17] but there still remains a gap to collectively evaluate the major risk factors, contributing in causing pre-diabetes. The risk factors studied are Body Mass Index (BMI), Glycated Haemoglobin (HbA1c) and Random blood glucose level developing prediabetes risk. HbA1c a diagnostic marker,[18] mainly used to assess blood glycaemic level of past 2 to 3 months in order to assess diabetes condition.[19] There are researches that strongly support that HbA1c is a biomarker for diabetes evaluation.[20]

BMI, the second risk factor included in this study, reveals a person's body adiposity [21,22] and its health status set by World Health Organization (WHO).[23] There are recent researches that report BMI as an indicator to assess impaired glucose metabolism in body developed due to insulin resistance.[24] Lastly, Random blood glucose is used as a factor to assess current blood glucose in body.[25] Previous population-based analysis suggest that random blood glucose was high in diabetic patients but was not significantly high in non-diabetic individuals.[26] Therefore, this study mainly focused on addressing the combined impact of Body Mass Index (BMI) and Glycated Haemoglobin (HbA1c) in causing pre-diabetes. Additionally, this study illuminates complex relationship of random blood glucose level with body mass index and glycated haemoglobin.

Moreover, the significance of this study addressed goals set by Sustainable Development Goal (SDG) of United Nations.[27] This study particularly focused SDG 3 (Good Health and Well-being) which mainly engrossed on the risk factors, Body Mass Index (BMI) and Glycated Haemoglobin (HbA1c) levels causing pre-diabetes and which should be assessed timely to prevent its progression and complication.[28]

The primary objective was to explore the effect of BMI and HbA1c levels in participants to assess pre-diabetes risk. Also, the research aimed to identify any link among BMI, HbA1c and random blood glucose level which could contribute in pre-diabetes occurrence.

Materials and Methods

A quantitative research approach was employed to provide complete understanding of the risk factors BMI and HbA1c levels in developing pre-diabetes. Data collection involved an experimental approach to assess risk factors. To ensure representativeness of data collected, probability sampling was utilized to collect data from population. University students (population) were chosen for this study. Participant selection was determined by inclusion criteria (candidates from age 20 to 25 years who were willing to participate) and exclusion criteria (participants with age above 25 years, having pregnancy, type 1 diabetes, type 2 diabetes or other serious medical condition and who were unwilling to comply with research experimental procedure), thus representing the target population. Both online (social media platform) and offline (Informational sessions, discussions, seminars, classroom presentations, announcements and different workshops) channels were imposed to exploit the engagement of participants.

HbA1c and blood glucose levels, both were assessed on the basis of diagnostic criteria set by American Diabetes Association (ADA).[29,30] Whereas, Body mass index was classification on the basis of World Health Organization (WHO) guidelines.[31]

To clarify the intricate interplay among factors BMI, HbA1c and random blood glucose level, experimental approach was employed.

For HbA1c testing, blood withdrawal procedures, following the guidelines for sample collection and venipuncture was conducted. To make sure the rationality and consistency of results, Bio-Active HbA1c Direct Diagnostic kit (Catalogue no. 1 0498 99 93 210) was selected and tests were run in science laboratory of UMT. The principle of this test was the interaction of antigen-antibody determining the concentration of HbA1c in blood. For sample preparation, venous blood of participants was taken using sterile techniques. 1ml distilled water was added in 20 µl whole blood sample and was made to stand for 10 mins. Then 8µl of sample was taken and R1 (Latex 0.15, Buffer, stabilizer) 300 µl was added, allowed to mix and incubated for 5 mins at 37 °c. Lastly, R2 (100 µl) was added in sample tube and incubated at 37 °c for 5 mins. Next, the sample readings were noted after running it in spectrophotometer at 630nm.

For random blood glucose testing, Evocheck glucometer (a handheld glucometer) was utilized showing the current glycemic index of participants. Finger was first cleaned with an alcohol swab to prevent any contamination before using lancet for blood sample collection. Then the blood sample was applied to test strip, which was prior inserted in glucometer. Within few seconds, random blood glucose level of the participant was recorded.

Anthropometric Measurements [32] were taken and Metric system formula[33] was used to evaluate Body Mass Index. Standardized devices like digital balances and stadiometer were used to measure both height and weight of participants. First, weight was measured while standing barefooted on weighing scale to minimize variability. Then, height was recorded by standing straight alongside the stadiometer. These inputs were used in Metric system formula yielding a numerical value indicating BMI.

Results

A total of 110, participants were enrolled in the study. Male (n=46, 41.8%) and female (n=64, 58.2%). Age 20 to 22 (n=56, 50.9%) and aged 23 to 25 years (n=54, 49%), shown in (Table I).

Table I: Baseline data of participants.

Characteristics	Number of participants	Percentage
Gender		
Male	46	41.8%
Female	64	58.2%
Age		
20 -22 years old	56	50.9%
23 -25 years old	54	49%

BMI, mean (± SD) was 25.19 (± 3.68) with values ranging from minimum 19.7 to maximum 31.6 showing healthy category (n=42, 38.2%), overweight (n=46, 41.8%) and obese (n=22, 20%) in (Table II).

Table II: Body Mass Index.

BMI	Mean ± SD	25.182 ± 3.6764	
	Minimum	19.7	
	Maximum	31.6	
		N	%
	Healthy weight (18.5-24.9 kg/m²)	42	38.2 %
	Overweight (25-29.9 kg/m²)	46	41.8 %
	Obese (>30 kg/m²)	22	20.0 %

HbA1c, mean± SD was 5.70 (± 0.29) with minimum value 5.3% to maximum value 6.2%, providing data for normal HbA1c (n=64, 58.2%) and prediabetes (n=46, 41.8%), underlining the range of glycaemic differences among target population, shown in (Table III).

Data from glucometer for random blood glucose level showed, Mean (± SD), 137 ± (10.2). Participants with normal blood glucose (n=65, 59.1%) and prediabetes (n=45,40.9%) as in (Table IV).

Relationship of HbA1c with BMI and Blood Glucose was assessed by Pearson's correlation test as shown in (Table 5). A positive significant correlation (r=0.46, p<0.00), indicated increase in BMI (falling in the category of overweight or obese) tend to increase HbA1c level in individuals making them pre-diabetic. Whereas, the relationship between HbA1c and blood glucose was non-significant correlation (r=0.18, p>0.05), representing that blood glucose values were not related with an increase in HbA1c levels.

Table III: HbA1c values testing.

HbA1c Levels	Mean ± SD	5.70 ± 0.294	
	Minimum	5.3%	
	Maximum	6.2%	
		N	**%**
	Normal HbA1c (below 5.6%)	64	58.2
	Prediabetes (5.7% to 6.5%)	46	41.8

Table IV: Blood Glucose Levels

Blood Glucose	Mean ± SD	137 ± 10.2	
	Minimum	120	
	Maximum	153	
		N	**%**
	Normal (120-140 mg/dl)	65	59.1
	Pre-diabetes (140-160 mg/dl)	45	40.9

Table V: Correlation Analysis of HbA1c with BMI and Blood Glucose levels.

Correlations				
		HbA1c	BMI	Blood Glucose
HbA1c	Pearson Correlation	1	.463**	0.182
	Sig. (2-tailed)		0.000	0.056
BMI	Pearson Correlation	.463**	1	0.018
	Sig. (2-tailed)	0.000		0.85
Blood Glucose	Pearson Correlation	0.182	0.018	1
	Sig. (2-tailed)	0.056	0.85	

****Correlation is significant at the 0.01 level (2-tailed).**

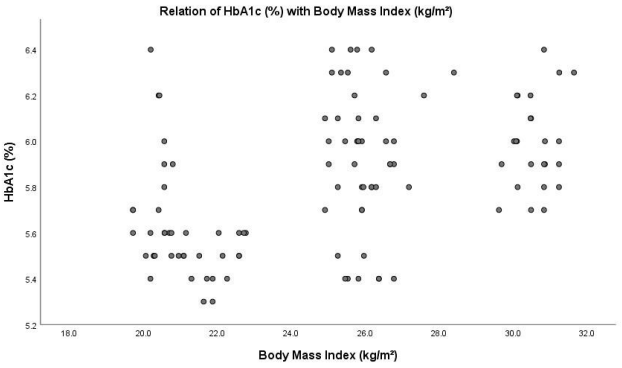

Figure 1. Relation of HbA1c values with BMI (kg/m²).

Scatter plot graph signifies direct relation of HbA1c with BMI, as shown in (Figure 1), where having high body mass index (BMI) was linked to have elevated HbA1c values.

Whereas, second graph (Figure 2) shows indirect or non-significant association of HbA1c with blood glucose.

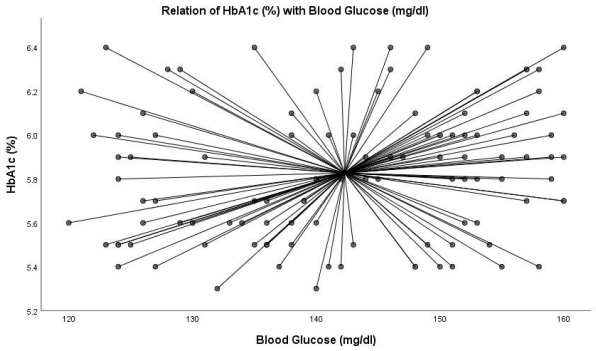

Figure 2. Relation of HbA1c values with Blood Glucose (mg/dl).

Discussion

Past researches had shown positive correlation between glycated haemoglobin and body mass index, demonstrating that elevated BMI value was linked with low blood glucose level.[34,35] A recent study illustrated significant impact of high BMI and HbA1c levels, especially participants who were obese (BMI 30 or >30 kg/m²) were having elevated HbA1c values.[36] This association of body mass index with glycated haemoglobin insisted the need of weight control strategies.[37] Likewise, reflective analysis including obese as target population confirmed that excessive weight gain (beyond healthy weight limit set by World Health Organization) spikes HbA1c, making the person prone to pre-diabetes.[38] Many studies on diabetic and non-diabetic population reported that without any weight control management strategy, worsening of HbA1c level along with association of other chronic diseases was observed.[39]

Similarly, there are studies that align with the result of this research ($r=0.463$, $p<0.001$) confirming linear relationship of both factors. On the other hand, there were articles that report negative correlation between random blood glucose and glycated haemoglobin level as done in this research ($r=0.182$, $p>0.05$).[36] Furthermore, there were researches that report HbA1c is a more reliable indicator for long term assessment of glycaemic index rather than random blood glucose testing, which could be influenced by diet or stress.[40] Conversely, there were also population-based studies conducted on diabetic patients that show a linear relation between glycated haemoglobin and random blood glucose, which is because of already existing diabetes condition.[41] Therefore, glycated haemoglobin is mainly considered a diagnostic marker to evaluate pre-diabetes.

Hence, the findings of this study in scripts the importance of assessing body mass index with glycated haemoglobin to predict risk of pre-diabetes. By measuring both of these factors, clinicians can more precisely identify individuals who are at risk of developing type 2 diabetes mellitus. Additionally, integrating BMI in diabetes screening model will overall enhance the evaluation of pre-diabetes. Moreover, personalized interventions and weight control strategy plans, could be helpful in reducing the onset of type 2 diabetes mellitus Also, implication of tailored diet plans in public health centre and hospital along with providing awareness in society, diabetes burden could be mitigated worldwide.

Recommendation and Limitation: First limitation was for not having a longitudinal plan to track body mass index variation impacting glycated haemoglobin levels, like fluctuation in HbA1c levels due to lifestyle changes. Secondly, restriction of age group limited the generalizability of study on other socioeconomic groups. Lastly, switching random blood glucose testing with oral glucose tolerance test could be effective in providing accurate glycaemic status of participants.

Conclusions

The study demonstrates a mixed picture addressing the research objective, which was “HbA1c levels and BMI in developing pre-diabetes risk”. As per the data and findings of this study, a positive significant correlation was found among BMI and HbA1c ($r= .463$, $p<0.01$) by Pearson’s correlation test. Moreover, it was noteworthy, that according to Pearson’s correlation test ($r=0.182$, $p>0.05$), HbA1c and blood glucose did not have any significant association.

Acknowledgement: The author would like to acknowledge Department of Life Sciences, UMT for continuous support all over this expedition.

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