Original article

Body Mass Index to Predict Pre-diabetes

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Abstract

Background: Early detection of the risk of pre-diabetes can lessen the likelihood of the development of diabetes mellitus. Various studies have shown a significant correlation between obesity and the incidence of pre-diabetes and diabetes. However, none of the studies has presented the value of fasting plasma glucose (FPG) or the oral glucose tolerance test (OGTT) as parameters for diagnosing pre-diabetes or diabetes. This study aimed to estimate the value of FPG and the OGTT to predict pre-diabetes based on body mass index (BMI).

Methods: This cross-sectional study was conducted in Kembaran sub district, Banyumas Regency, Indonesia. The research sample consisted of 231 apparently healthy respondents (not showing any clinical symptoms of diabetes) who were underweight, normal weight, overweight and obese in terms of their BMI, and the sample was selected through random sampling. All samples were measured for BMI, FPG, and OGTT. Data were then analyzed with linear regression.

Results: From 231 subjects, 133 (57.5%) were considered as normal, while 90 (39.0%) were diagnosed with pre-diabetes. We were unable to predict eight (3.5%) subjects. There was a positive correlation between BMI, FPG and the OGTT (FPG: r0.543; p<0.01; FPG prediction: 56.800+2.232*BMI), (OGTT: r0.462; p<0.01; OGTT prediction: 85.231+2.202*BMI).

Conclusions and recommendation: BMI can be utilized as the prediction of pre-diabetic occurrence; a person the apparently healthy but has a BMI ≥ 25kg/m^2 is considered to have pre-diabetes. [*Ethiop.J. Health Dev.* 2019; 33(1):38-45]

Keywords: Body mass index; pre-diabetes; fasting plasma glucose; oral glucose tolerance test; Indonesia

Background

Diabetes mellitus (DM) has become a global health problem that requires attention because of the increasing number of sufferers. In 2015, with an estimated 10 million DM cases, Indonesia had the seventh highest number of DM cases globally, behind China, India, USA, Brazil, Russia and Mexico (1). The prevalence of diabetes in Indonesia is increasing – from 1.1% in 2007 to 1.5% in 2013 and increase to 2.0% in 2018 (2–4). In the research location of this study, Banyumas Regency, Indonesia, in 2015 there were around 7.738 people suffering from DM (5).

DM is often unidentified and routine blood sugar checks must be carried out to diagnose it (6). The American Diabetes Association (ADA) recommends that routine diabetes screening should be done at the age of 45, because the earlier that DM is detected, the quicker treatment can be given to abate the progress of the disease (7).

One of the risk factors suspected as the cause of diabetes from various studies is overweight or obesity. National survey in 2007, the number of obese people in Indonesia is 19.1% and in 2013 the number of obesity in adults in Indonesia amounted to 15.4% and in 2018 increased to 21.8%. The prevalence of central obesity (abdominal) in the Indonesian adult population in 2007 is 26.6%, higher than the prevalence in 2007 (18.8%), and in 2018 increased to 31.0% (2–4)

Body mass index (BMI) is the most common indicator utilized to measure the level of overweight and obesity in adults (8). From two National surveys, Study to Help Improve Early evaluation and management of risk factors Leading to Diabetes (SHIELD) 2004 and the National Health and Nutrition Examination Surveys (NHANES) 1999–2002, average BMI in diabetics was 27.8 kg/m2 for SHIELD and 27.9 kg/m2 for NHANES. For each condition, more than 75% of patients had a BMI ≥25 kg/m2 (9), which is attributed to environmental factors and unhealthy lifestyles, such as overeating, fatty food preferences, and a lack of physical activity (10,11).

Approximately 70% of obese patients and more than 50% of overweight patients experience a decrease in glucose tolerance. According to the Nurses Health Study, weight gain is a strong predictor of the risk of Type 2 DM (12). An increase in weight of >20kg after the age of 18 years represents an increased risk of DM of up to 12 times, and 61 times greater if the BMI is above 35kg/m^2 (13).

Pre-diabetes is a warning sign before a person actually suffers from diabetes. Pre-diabetes itself is characterized by high levels of glucose or sugar in the blood due to insulin resistance. Insulin resistance is an early symptom of Type 2 diabetes. Although it is not yet diabetes, pre-diabetes should to be treated immediately, because it is possible to develop into diabetes within 10 years. This pre-diabetes condition can still be overcome by improving lifestyle. If early intervention is carried out, the risk of diabetes can be delayed or even disappear, therefore early detection is required in order to prevent the condition of pre-diabetes becoming DM.

Various studies have proven a significant correlation between obesity and the incidence of pre-diabetes and

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diabetes (14,15). Obesity sufferers are three times more likely to suffer from pre-diabetes (16,17). However, these studies did not include the predicted value of fasting plasma glucose (FPG), the oral glucose tolerance test (OGTT), and hemoglobin A1c (HbA1c) as parameters for diagnosing pre-diabetes or diabetes. Obtaining information about predictive values of fasting blood sugar levels or the value of the OGTT based on BMI values is more beneficial than information on the correlation of obesity to the risk of pre-diabetes/diabetes.

To prevent the increasing number of diabetic incidents in Indonesia, it is essential to identify the early diagnosis of pre-diabetes in individuals. To diagnose pre-diabetes and diabetes can be done by checking FPG or OGTT or HbA1c. The examination requires special skills, such as health workers using certain techniques and tools. Due to this limitation of examination, it is common for a person's pre-diabetes to remain unidentified.

Therefore, it is very important to conduct research on predicting the diagnosis of pre-diabetesin asimple way. This study aims to estimate FPG, OGTT values and predict pre-diabetes based on BMI measurements.

Methods

Study design:This is a cross-sectional study, which takes BMI asthe independent variable and FPG and OGTT as dependent variables (18,19).

Study population and sample size: The study was conducted in Kembaran sub-district, Banyumas Regency, Indonesia, from December 2017 to August 2018. The study population were residents of Kembaran and individuals selected through the inclusion criteria were apparently healthy(not showing symptoms of *trias*, i.e. clinical symptoms of diabetes) based on the results of interviews and medical records from Kembaran Public Health Center; aged between 30-45 years; classified under the BMI categories of underweight, normal and overweight or obese; and had no hereditary diabetes. Samples from inclusion criteria were then selected randomly and divided into four categories equally, namely: underweight, normal, overweight and obese.

The study design is cross-sectional. The sample size was the calculation formula for cross-sectional study (Type 1 error 5%, d=0.05 and prevalence proportion of obese patients was 21.8%) (20,21), the sample was selected through simple random sampling. The sample estimation obtained was 254, but the number of samples collected in the analysis was 231 respondents. Twenty-three samples were not selected in the analysis, some samples were not found, most of the samples were obese category, and some samples did not follow the research.

Measurements: In this study, BMI was an independent variable, while FPG and OGTT were dependent variables. Respondents' weights and heights were measured using weighing scales and height gauges, then respondents were measured for their BMI (underweight <18.5kg/m^2, normal weight 18.5-24.9kg/m^2, overweight 25-29.9kg/m^2, Class I obesity 30-34.9kg/m^2, Class II obesity 35-39.9kg/m^2, Class III obesity ≥40kg/m^2) (22,23). Next, fasting for 8-12 hours was carried out before performing the FPG measurement (normal: below 110mg/dl; impaired fasting glucose: between 110mg/dl and 125mg/dl; diabetic:126mg/dl and above) (24). Finally,the OGTT was carried out by giving respondents 75g of glucose in 250ml of water orally, and blood sugar levels were measured after two hours (normal: below 140mg/dl; impaired glucose tolerance: between 140mg/dl and <200mg/dl; diabetic: 200mg/dl and above). Glucose levels were measured using aglucometer. The pre-diabetes diagnosis was assessed from two parameters of examination: FPG and OGTT (25).

Statistical analysis: Data for BMI, FPG and OGGT were analyzed using SPSS version 21 through a simple linear regression analysis. Terms of reliability from data regression analysis were conducted inthis study by implementing normality, linearity and heteroscedasticity tests (26–28).

Ethical considerations

This study obtained approval from the health research ethics committee at the Universitas Muhammadiyah Purwokerto. The purpose of the study was explained to the participants before the study. All participants signed consent forms voluntarily. All patient data is kept confidential and is only used for research purposes.

Results

Characteristics of the subjects: The characteristics of the subjects in this study are shown in Table 1. There were 115 (49.8%) males and 116 (50.2%) females. The average age of the subjects was 39.52 ± 4.93 years old. In terms of BMI, 77 subjects (33%) were underweight; 77 (33%) were normal weight; 74 (32%) were overweight; and three (1.3%) were Class I obese. None of the subjects were Class II or III obese. In total, 133 (57.5%) subjects were diagnosed as normal, while 90 (39.0%) subjects were diagnosed with pre-diabetes, and eight (3.5%) subjects could not be diagnosed.

Table 1. **Characteristics of the subjects**

Characteristic	Results
Sex	
Male	115 (49.8%)
Female	116 (50.2%)
Age, yr (mean, SD)	39.52±4.93
BMI	
Underweight	77 (33%)
Normal weight	77 (33%)
Overweight/Pre-obesity	74 (32%)
Class I obesity	3 (1%)
Class II, III obesity	0 (0%)
FPG	
Normal	114 (61%)
Impaired fasting glucose	90 (39%)
Diabetic	0 (0%)
OGTT	
Normal	133 (57.6%)
Impaired glucose tolerance	98 (42.4%)
Diabetic	0 (0%)
Diagnosis	
Normal	133 (57.5%)
Pre-diabetes	90 (39.0%)
Diabetes	0 (0%)
Cannot be diagnosed	8 (3.5%)

The underweight category of BMI obtained an average FPG of 91mg/dl and OGTT of 122mg/dl. Of the 77 underweight BMI subjects, 12 subjects were diagnosed with pre-diabetes (FPG 110-125mg/dl and OGTT140-199mg/dl). In the category of normal BMI subjects, the average FPG was 96mg/dl and the OGTT was 129mg/dl, and 20 subjects out of 77 subjects in the normal BMI category were diagnosed with pre-diabetes. In overweight BMI subjects, the average FPG was 114mg/dl and OGTT was 148mg/dl, and 61 subjects out of 74 were diagnosed with pre-diabetes. In subjects in the BMI obese category, the average FPG was 116mg/dl and the OGTT was 150mg/dl. All of the subjects in the obese BMI category were diagnosed to have pre-diabetes

Correlation and linear regression of BMI, FPG and OGTT: The results of the analysis revealed that there was a positive correlation between BMI and FPG (r: 0.543, p<0.01): the higher the BMI value presented, the higher the FPG value obtained. BMI contributed 30% (r^2) to the variation in FPG values, while the remaining 70% was affected by other factors. Based on the results of the coefficient analysis, it was assumed that FPG (dependent variable) compared to BMI (independent variable) with the equation FPG: 56,800 + 2,232*BMI.

In addition, the analysis presented a positive correlation between BMI and OGTT (r: 0.462, p<0.01), which meant that an increase of BMI value would affect the increase of the OGTT value. BMI value contributed 21% (r^2) to the variation in OGTT values, while the rest (79%) was affected by other factors. Based on the coefficient analysis, we could also assume the OGTT value (dependent variable) based on the BMI (independent variable) value with the equation OGTT: 85,231 + 2,202*BMI.

Scatter plots (linear regression) correlation between BMI and FPG and OGTT is shown in Figure 1.

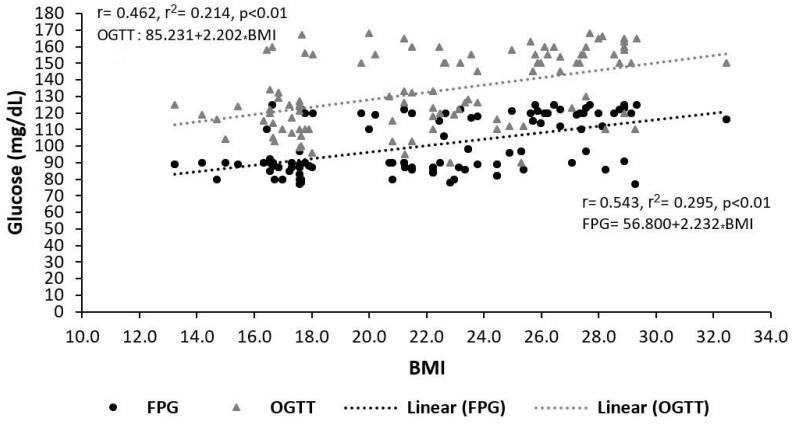


Figure 1: **Scatter plots of BMI in relation to FPG and OGTT**

The results of the residual analysis to assess the regression model can be seen in Figure 2.

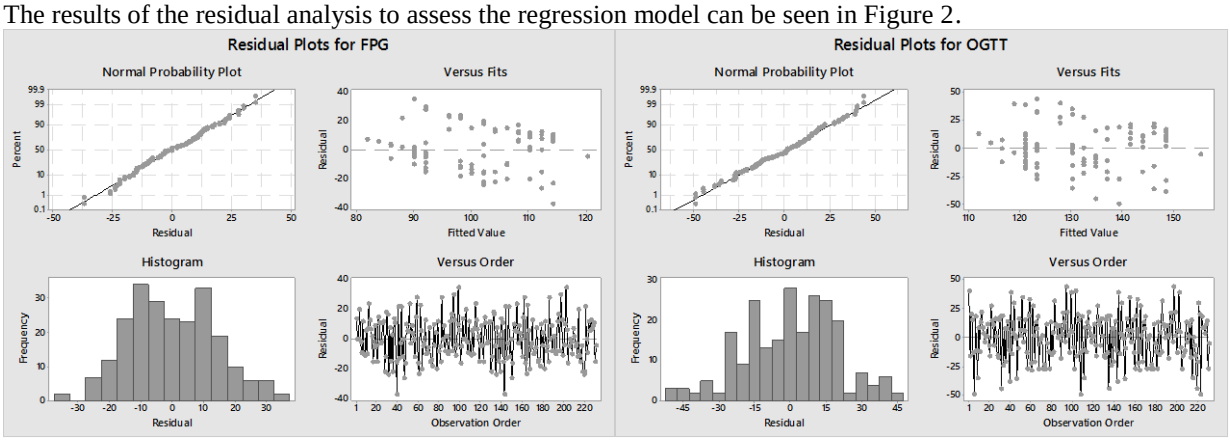


Figure 2: **Residual plot analysis**

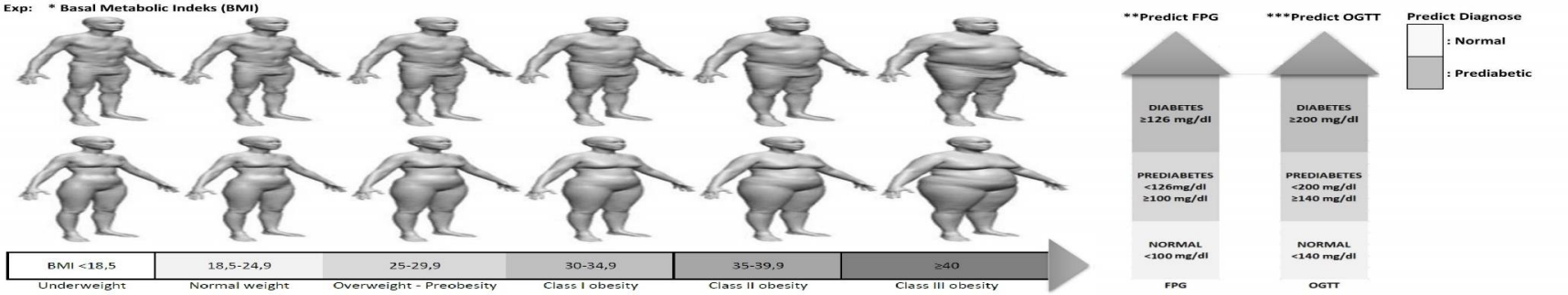
The results of residual analysis on normal probability plots showed that the data were normally distributed, as seen from the points which always follow and are close to a diagonal line. The analytical results of the normality test by Kolmogorov-Smirnov formula obtained $p>0.05$, which proved that the data were normally distributed. The results of linearity analysis through ANOVA showed $p<0.05$, which proved that the data on BMI, FPG and OGTT were linear. The residual results on plot versus fit presented plots were spread evenly above and below the 0 axis without forming a certain pattern. The results of heteroscedasticity test using the Glejser test obtained $p>0.05$, which meant that there were no symptoms of heteroscedasticity in the regression model, or data were identical. The results of the residual analysis on plot versus older discovered that the plot was spread evenly above and below the 0 axis without forming a specific pattern. Thus, the data were interpreted as independent and there was no autocorrelation (20-22).

Pre-diabetic prediction: In this study, pre-diabetes could be predicted from BMI values using the equations obtained in the statistical analysis above. Pre-diabetes diagnosis was determined based on two parameters: if FPG value was between 110-125mg/dl and OGTT value was between 140-199mg/dl. This study assumed that a person with a BMI ≥25 value was considered to have pre-diabetes (FPG: 56,800 + 2,232∗25 = 112.6mg/dl) and (OGTT: 85,231 + 2,202∗25 = 140.28mg/dl).

Prediction results of pre-diabetes based on BMI values are shown in Table 2.

Table 2: **Estimated FPG, OGTT values based on body mass index and predicting pre-diabetes**

	Weight																						
Height	45,5	47,7	50,0	52,3	54,5	56,8	59,1	61,4	63,6	65,8	68,2	70,5	72,7	75,0	77,3	79,5	81,8	84,1	86,4	88,6	90,9	93,2	95,5	97,7
152,5	19* 99** 127***	20* 101** 129***	21* 104** 131***	22* 106** 134***	23* 108** 136***	24* 110** 138***	25* 113** 140***	26* 115** 142***	27* 117** 145***	28* 119** 147***	29* 122** 149***	30* 124** 151***	31* 126** 153***	32* 128** 156***	33* 130** 158***	34* 133** 160***	35* 135** 162***	36* 137** 165***	37* 139** 167***	38* 142** 149***	39* 144** 171***	40* 146** 173***	41* 148** 176***	42* 151** 178***
154,9	18* 97** 125***	19* 99** 127***	20* 101** 129***	21* 104** 131***	22* 106** 134***	23* 108** 136***	24* 110** 138***	25* 113** 140***	26* 115** 142***	27* 117** 145***	28* 119** 147***	29* 122** 149***	30* 124** 151***	31* 126** 153***	32* 128** 156***	33* 130** 158***	34* 133** 160***	35* 135** 162***	36* 137** 165***	36* 137** 165***	37* 139** 167***	38* 142** 149***	39* 144** 171***	40* 146** 173***
157,4	18* 97** 125***	19* 99** 127***	20* 101** 129***	21* 104** 131***	22* 106** 134***	22* 106** 134***	23* 108** 136***	24* 110** 138***	25* 113** 140***	26* 115** 142***	27* 117** 145***	28* 119** 147***	29* 122** 149***	30* 124** 151***	31* 126** 153***	32* 128** 156***	33* 130** 158***	33* 130** 158***	34* 133** 160***	35* 135** 162***	36* 137** 165***	37* 139** 167***	38* 142** 149***	39* 144** 171***
160,0	17* 95** 123***	18* 97** 125***	19* 99** 127***	20* 101** 129***	21* 104** 131***	22* 106** 134***	23* 108** 136***	24* 110** 138***	24* 110** 138***	25* 113** 140***	26* 115** 142***	27* 117** 145***	28* 119** 147***	29* 122** 149***	30* 124** 151***	31* 126** 153***	32* 128** 156***	32* 128** 156***	33* 130** 158***	34* 133** 160***	35* 135** 162***	36* 137** 165***	37* 139** 167***	38* 142** 149***
162,5	17* 95** 123***	18* 97** 125***	18* 97** 125***	19* 99** 127***	20* 101** 129***	21* 104** 131***	22* 106** 134***	23* 108** 136***	24* 110** 138***	24* 110** 138***	25* 113** 140***	26* 115** 142***	27* 117** 145***	28* 119** 147***	29* 122** 149***	30* 124** 151***	31* 126** 153***	31* 126** 153***	32* 128** 156***	33* 130** 158***	34* 133** 160***	35* 135** 162***	36* 137** 165***	37* 139** 167***
165,1	16* 93** 120***	17* 95** 123***	18* 97** 125***	19* 99** 127***	20* 101** 129***	20* 101** 129***	21* 104** 131***	22* 106** 134***	23* 108** 136***	24* 110** 138***	25* 113** 140***	25* 113** 140***	26* 115** 142***	27* 117** 145***	28* 119** 147***	29* 122** 149***	30* 124** 151***	30* 124** 151***	31* 126** 153***	32* 128** 156***	33* 130** 158***	34* 133** 160***	35* 135** 162***	35* 135** 162***
167,5	16* 93** 120***	17* 95** 123***	17* 95** 123***	18* 97** 125***	19* 99** 127***	20* 101** 129***	21* 104** 131***	21* 104** 131***	22* 106** 134***	23* 108** 136***	24* 110** 138***	25* 113** 140***	25* 113** 140***	26* 115** 142***	27* 117** 145***	28* 119** 147***	29* 122** 149***	29* 122** 149***	30* 124** 151***	31* 126** 153***	32* 128** 156***	33* 130** 158***	34* 133** 160***	34* 133** 160***
170,1	15* 90** 118***	16* 93** 120***	17* 95** 123***	18* 97** 125***	18* 97** 125***	19* 99** 127***	20* 101** 129***	21* 104** 131***	22* 106** 134***	22* 106** 134***	23* 108** 136***	24* 110** 138***	25* 113** 140***	25* 113** 140***	26* 115** 142***	27* 117** 145***	28* 119** 147***	29* 122** 149***	29* 122** 149***	30* 124** 151***	31* 126** 153***	32* 128** 156***	33* 130** 158***	33* 130** 158***
172,7	15* 90** 118***	16* 93** 120***	16* 93** 120***	17* 95** 123***	18* 97** 125***	19* 99** 127***	19* 99** 127***	20* 101** 129***	21* 104** 131***	22* 106** 134***	22* 106** 134***	23* 108** 136***	24* 110** 138***	25* 113** 140***	25* 113** 140***	26* 115** 142***	27* 117** 145***	28* 119** 147***	28* 119** 147***	29* 122** 149***	30* 124** 151***	31* 126** 153***	32* 128** 156***	32* 128** 156***
175,2	14* 88** 116***	15* 90** 118***	16* 93** 120***	17* 95** 123***	17* 95** 123***	18* 97** 125***	19* 99** 127***	20* 101** 129***	20* 101** 129***	21* 104** 131***	22* 106** 134***	22* 106** 134***	23* 108** 136***	24* 110** 138***	25* 113** 140***	25* 113** 140***	26* 115** 142***	27* 117** 145***	28* 119** 147***	28* 119** 147***	29* 122** 149***	30* 124** 151***	31* 126** 153***	31* 126** 153***
177,8	14* 88** 116***	15* 90** 118***	15* 90** 118***	16* 93** 120***	17* 95** 123***	18* 97** 125***	18* 97** 125***	19* 99** 127***	20* 101** 129***	20* 101** 129***	21* 104** 131***	22* 106** 134***	23* 108** 136***	23* 108** 136***	24* 110** 138***	25* 113** 140***	25* 113** 140***	26* 115** 142***	27* 117** 145***	28* 119** 147***	28* 119** 147***	29* 122** 149***	30* 124** 151***	30* 124** 151***
180,3	14* 88** 116***	14* 88** 116***	15* 90** 118***	16* 93** 120***	16* 93** 120***	17* 95** 123***	18* 97** 125***	18* 97** 125***	19* 99** 127***	20* 101** 129***	21* 104** 131***	21* 104** 131***	22* 106** 134***	23* 108** 136***	23* 108** 136***	24* 110** 138***	25* 113** 140***	25* 113** 140***	26* 115** 142***	27* 117** 145***	28* 119** 147***	29* 122** 149***	30* 124** 151***
182,8	13* 86** 114***	14* 88** 116***	14* 88** 116***	15* 90** 118***	16* 93** 120***	17* 95** 123***	17* 95** 123***	18* 97** 125***	19* 99** 127***	19* 99** 127***	20* 101** 129***	21* 104** 131***	21* 104** 131***	22* 106** 134***	23* 108** 136***	23* 108** 136***	24* 110** 138***	25* 113** 140***	25* 113** 140***	26* 115** 142***	27* 117** 145***	27* 117** 145***	28* 119** 147***	29* 122** 149***
185,4	13* 86** 114***	13* 86** 114***	14* 88** 116***	15* 90** 118***	15* 90** 118***	16* 93** 120***	17* 95** 123***	17* 95** 123***	18* 97** 125***	19* 99** 127***	19* 99** 127***	20* 101** 129***	21* 104** 131***	21* 104** 131***	22* 106** 134***	23* 108** 136***	23* 108** 136***	24* 110** 138***	25* 113** 140***	25* 113** 140***	26* 115** 142***	27* 117** 145***	27* 117** 145***	28* 119** 147***
187,9	12* 84** 112***	13* 86** 114***	13* 86** 114***	14* 88** 116***	15* 90** 118***	16* 93** 120***	16* 93** 120***	16* 93** 120***	18* 97** 125***	18* 97** 125***	19* 99** 127***	19* 99** 127***	20* 101** 129***	21* 104** 131***	21* 104** 131***	22* 106** 134***	23* 108** 136***	23* 108** 136***	24* 110** 138***	24* 110** 140***	25* 113** 140***	25* 113** 140***	26* 115** 142***	27* 117** 145***	27* 117** 145***
190,5	12* 84** 112***	13* 86** 114***	13* 86** 114***	14* 88** 116***	15* 90** 118***	15* 90** 118***	15* 90** 118***	15* 90** 118***	17* 95** 123***	18* 97** 125***	18* 97** 125***	19* 99** 127***	20* 101** 129***	21* 101** 129***	22* 104** 131***	21* 104** 131***	22* 106** 134***	23* 108** 136***	23* 108** 136***	24* 110** 138***	25* 113** 140***	25* 113** 140***	26* 115** 142***	26* 115** 142***
193,0	12* 84** 112***	12* 84** 112***	13* 86** 114***	14* 88** 116***	14* 88** 116***	15* 90** 118***	15* 90** 118***	15* 90** 118***	17* 95** 123***	17* 95** 123***	18* 97** 125***	17* 95** 123***	19* 99** 127***	20* 101** 129***	20* 101** 129***	21* 104** 131***	22* 106** 134***	22* 106** 134***	23* 108** 136***	23* 108** 136***	24* 110** 138***	25* 113** 140***	25* 113** 140***	26* 115** 142***



Discussion

This study predicted the occurrence of pre-diabetes based on the BMI values of individuals considered to be healthy, and with no clinical symptoms of diabetes or other diseases. The results indicate that an increase in BMI value is positively related to an increase in FPG and OGTT results.

The obesity level and duration were associated with an increased risk of pre-diabetes, which could lead to DM (8,29), because the increase in blood sugar levels was in line with the increase in BMI (30). The results of the study indicated that heaviera person was, the greater the chance of getting pre-diabetes.

The role of obesity in insulin resistance is explained in many theories. One theory states that fat tissue is also an active endocrine network associated with the liver and muscles through the release of intermediate substances which later affect the role of insulin. The accumulation of fat tissue might end with the onset of insulin resistance. Insulin resistance makes glucose difficult to enter cells, resulting in increased levels of glucose in the blood (31).

Obesity condition performs a significant decrease in adiponectin expression (32,33). Adiponectin is a specific cytokine in adipose tissue which has the structure of collagen VIII, collagen X and C1q complement component. Adiponectin affects insulin sensitivity by increasing tyrosine phosphorylation in insulin receptors and insulin receptor substrate in muscle cells. Adiponectin reduction results in a decrease in hepatic and peripheral insulin sensitivity (35).

Low-grade chronic inflammation also contributes to the process of a metabolic syndrome characterized by the increased of lipopolysaccharides (LPSs), TNF-*α*, IL-6, leptin, resistin (32,36). Increased TNF-α in the fat tissue of obese patients presentsa direct association with insulin resistance (37). TNF-α enhances the expression regulation of protein cleavage-activating protein (SCAP) and improves triglyceride synthesis, which is likely to support the process of hepatocyte and pancreatic steatosis (38). Hepatocyte and pancreatic steatosis cause an increase in the gluconeogenesis process in the liver and a decrease in insulin secretion in the pancreas (39).

Serum resistin hormone in levels were significantly higher in obese subjects, and were positively correlated with BMI (41). Increased resistin hormone (resistance to insulin) was a trigger for insulin resistance (42).

Leptin hormone has a positive correlation with total fat mass, fat mass peripherals and central fat mass (38). Increased leptin hormone in obese people is due to cell resistance to this hormone, so that the body produces the hormone in large quantities (43). One of the functions of leptin is to improve metabolic rate (44). The reduction or resistance of leptin hormone affects deterioration of the body's metabolism, resulting in a rise in body weight by increasing gluconeogenesis in the liver (31).

The correlation process between obesity and the appearance of DM is indicated in Figure 4 (31,32,42–45,33–39,41-40).

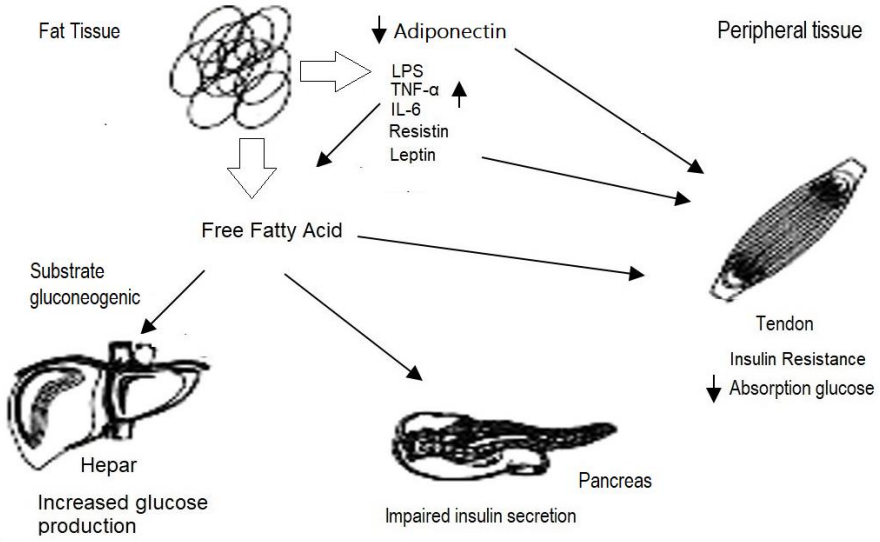


Figure 4: **The correlation process of obesity and diabetes mellitus**

Note: LPS = lipopolysaccharide; TNF-α= tumor necrosis factor alpha; IL-6 = interleukin-6.

The results of this study predicted that a person with BMI≥25kg/m^2 was likely to suffer from pre-diabetes, because the obtained equation calculation in the regression analysis showed BMI of 25kg/m^2 would have an estimation of FPG value 112.6mg/dl and OGTT value of 140.28mg/dl, so that the FPG and OGTT values were beyond normal values. This study supports previous studies which show that individuals

with a BMI>25kg/m^2 are at risk of developing pre-diabetes(16,46,47). Therefore, weight management is important in the prevention of pre-diabetic development (30).

Conclusion and recommendations

This study shows that the value of someone's FPG and OGTT as a basis for establishing pre-diabetes diagnosis can be predicted from their BMI value. Health offices could consider the prediction tables for the results of this study as material for health education for the community regarding obesity related to pre-diabetes. Further studies to assess the sensitivity and specificity to the results of predictions in the study are necessary to evaluate the extent of the accuracy of the predictions.

Strengths and limitations of the study

The results of this study make it relatively easy for people to estimate their FPG and OGTT values as markers of pre-diabetes and diabetes diagnosis without having to have a medical check-up. The estimated number of samples (273) was not in accordance with the results of the final sample used in this study (231), thus it may have reduced the level of accuracy of the findings. Samples in the category of Class II and III obesity were not obtained in the study.

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