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Effect of White Rice Substitution with Sorghum Rice on Beta Cell Function and Insulin Resistance in Prediabetes

Efecto de la sustitución del arroz blanco por arroz con sorgo sobre la función de las células beta y la resistencia a la insulina en la prediabetes

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SUMMARY

Background: *Decrease in the function of beta cells and insulin resistance (IR) is found in prediabetes. Sorghum rice is a staple food substitute for white rice which has low GI and GL, high fiber, rich in polyphenols which can improve IR and beta cell function. This study aims to analyze the effect of sorghum rice on beta cell function and IR in prediabetes.*
Methods: *An open experimental study with a pre-posttest design on prediabetes patients at Bojonegoro Police Polyclinic and Bojonegoro Bhayangkara Hospital. Treatment is standard lifestyle intervention plus the substitution of white rice with sorghum rice for 7 days compared to a standard lifestyle. IR examination using the HOMA-IR formula and beta cell function with HOMA-B.*
Results: *Standard lifestyle intervention plus diet substitution with sorghum rice for 7 days in prediabetes patients resulted in FBG of 7.5 mg/dL ($p=0.014$) and an increase in HOMA-B of 85.3 % ($p= 0.019$), while the decrease in HOMA-IR was not significant ($p=0.060$). When compared with the standard lifestyle, this intervention was better but not statistically significant ($p>0.05$).*
Conclusion: *Standard lifestyle intervention plus diet substitution with sorghum rice for 7 days influences FBG and beta cell function in prediabetic patients but not on IR.*

Keywords: *Prediabetes, rice sorghum, beta cell function, insulin resistance.*

RESUMEN

Antecedentes: *Disminución de la función de las células beta y resistencia a la insulina (RI) encontrada en la prediabetes. El arroz con sorgo es un alimento básico sustituto del arroz blanco que tiene un IG y un CG bajos, un alto contenido de fibra y es rico en polifenoles que pueden mejorar la función de las células beta y la RI. Este estudio tiene como objetivo analizar el efecto del arroz sorgo sobre la función de las células beta y la IR en la prediabetes.*
Métodos: *Estudio experimental abierto con un diseño de pre-postest en pacientes con prediabetes en el*

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Policlínico de Policía de Bojonegoro y el Hospital Bojonegoro Bhayangkara. El tratamiento es una intervención de estilo de vida estándar más sustitución de arroz blanco con arroz de sorgo durante 7 días en comparación con un estilo de vida estándar. Examen IR utilizando la fórmula HOMA-IR y función de células beta con HOMA-B.

Resultados: *La intervención estándar en el estilo de vida más la sustitución de la dieta con arroz con sorgo durante 7 días en pacientes con prediabetes resultó en FBG de 7,5 mg/dL (p=0,014) y aumento en HOMA-B de 85,3 % (p= 0,019), mientras que la disminución en HOMA-IR no fue significativo (p=0,060). Cuando se comparó con el estilo de vida estándar, esta intervención fue mejor pero no estadísticamente significativa (p>0,05).*

Conclusión*: La intervención estándar en el estilo de vida más la sustitución de la dieta con arroz con sorgo durante 7 días influye en la FBG y la función de las células beta en pacientes prediabéticos, pero no en la RI.*

Palabras clave*: Prediabetes, arroz sorgo, función de las células beta, resistencia a la insulina.*

INTRODUCTION

Prediabetes is a condition where there is an increase in blood sugar or glycated hemoglobin (HbA1c) above normal but does not meet the criteria for diabetes (1). Prediabetes has a risk of 2-10 times becoming diabetes mellitus (DM) and about 1/3 of cases of prediabetes will develop DM. Prediabetes itself is a toxic condition that causes an increase in the occurrence of both macro and microvascular complications (2). The prevalence of prediabetes in Indonesia continues to increase, currently ranking 3rd after China and America at 29.1 million (3). This increase is since health workers and the public, in general, do not know clearly what prediabetes is and how it is managed (4).

Even though prediabetes does not meet the criteria for diabetes, there is a decrease in pancreatic beta cell function by 70 %-80 %, a decrease in beta cell volume by 30 %-40 %, and insulin resistance (IR) that has reached its maximum or is close to maximum (5). The risk of macrovascular complications in the form of cardiovascular disease increases by 13 %, coronary heart disease by 10 %, and stroke by 6 % in prediabetes. The risk of microvascular complications also increases, namely retinopathy by 8 %, microalbuminuria by 15.5 %, and polyneuropathy by 11 %-25 %. 16.6 % of patients with chronic kidney disease are prediabetic (6,7).

Lifestyle modification is the main treatment for prediabetes which includes regulation of dietary intake and activity as well as physical exercise (1,4). One of the characteristics of the Indonesian population is the consumption of white rice as a staple food that has a high glycemic index and glycemic load which is one of the causes of prediabetes (4,8), so it is necessary to replace white rice with other staple foods that has a low glycemic index (GI) and glycemic load (GL).

Sorghum rice is a food substitute for white rice which is processed from the sorghum (Sorghum bicolor) plant which has low GI and GL. Sorghum rice has great potential as nutritional therapy in diabetes and prediabetes because it has a low GI and GL (9,10). Human studies using sorghum bread as a substitute for wheat bread also appear to be effective in lowering post-meal blood sugar and insulin concentrations (9,10). However, existing studies have only investigated blood sugar levels and insulin concentrations after a single meal replacement. In addition, there are no studies that have assessed the replacement of staple foods in the form of white rice with sorghum rice for a longer period. Thus, we investigated the effect of the substitution of white rice with sorghum rice for 7 days on IR and beta cell function in prediabetic patients receiving standard lifestyle interventions. This work attempted to analyze the effect of sorghum rice on beta cell function and IR for prediabetes in Bojonegoro Police Polyclinic and Bojonegoro Bhayangkara Hospital.

MATERIALS AND METHODS

This open experimental study was conducted between March and April 2022. The population was prediabetic patients at Bojonegoro Police Polyclinic and Bojonegoro Bhayangkara Hospital. In this design, there is a control group, namely subjects who get an education on healthy living behavior with a white rice diet, and a treatment group who gets an education on healthy living behavior and a sorghum rice diet for 7 days. Under the supervision of general practitioners, nutritionists, and health affairs officers at the Bojonegoro Police Polyclinic and Bojonegoro Bhayangkara Hospital, parameters of FBG, HOMA-IR, and HOMA-B were measured before and after treatment (pre and posttest).

The participant had been informed about the goal, procedure, confidentiality guarantee, and the right to refuse to be the subject of research through the form of information for consent. After the participant had agreed to participate in the research, they signed the informed consent form. This research proposal had been certified by the Health Research Ethics Committee in the Faculty of Medicine Airlangga University for ethical clearance (certificate number 52/EC/KEPK/FKUA/2022).

They were recruited using the randomized block technique, by dividing the first three groups, namely normal weight, overweight, and obese. After that, randomization was carried out to be divided into two control and treatment groups. The number of samples required was calculated using a comparative formula with paired numerical data of more than 1 group (11), with the result being 22 participants. Participants included in this study were 18 to 58 years of age, diagnosed with prediabetes in accordance with the PERKENI criteria (12), willing to participate in lifestyle change interventions from polyclinic and hospital, willing to sign informed consent, and have a cellphone with a camera for diet monitoring. Those with pregnant; had malignancy; diabetes; and infection condition, taking blood sugar lowering drugs; steroids; and obesity drugs, had undergone cirrhosis hepatitis Child-Pugh B and C, and had glomerular filtration rate < 60 mL/min/1.73 m^2 were excluded from the study.

The independent variables in this study were sorghum rice and standard lifestyle, while the dependent variables were FBG, HOMA-IR, and HOMA-B. The difference in Fasting glucose, HOMA-IR, and HOMA-B before and after intervention in the treatment group was statistically analyzed using the Wilcoxon Signed Rank test. Measurement of FBG after the participant fasting for 8 hours. HOMA-IR is a mathematical model that estimates the level of insulin resistance based on FBG and basal insulin levels. HOMA-R result is obtained from HOMA-IR = (FBG level in mmol/L x basal insulin level in mIU/mL) / 22.5. HOMA-B is a mathematical model that estimates pancreatic beta cell function based on FBG and basal insulin levels. HOMA-B result is obtained from HOMA-B = (20 × basal insulin level in mIU/mL)/(FBG in mmol/L 3.5 (13).

RESULT

In this study, there were 25 participants involved. Table 1 displays the participants' characteristics. The number of male and female samples was relatively the same where more male samples were given white rice treatment and more female samples were given sorghum rice treatment. The p-value in the sex difference test based on the control and treatment groups obtained a value of 0.158, which indicates that there is no significant differences between sex.

Data on changes in Fasting glucose, insulin, HOMA-IR, and HOMA-B before and after the intervention in the treatment group are shown in Table 2, while data on differences of Fasting glucose, HOMA-IR, HOMA-B before and after intervention in the treatment group using the Wilcoxon signed Rank test (data not normal) is shown in Table 3.

The intervention group of this study showed a significant difference in the value of FBG and HOMA-B pre and post-intervention, while the difference in HOMA-IR was not statistically significant (Table 3).

This study found the FBG delta for the control group with a mean of -2.62 ± 6.89 and a median of -2.00 (-9.00 – 15.00) and a mean intervention group of -7.50 ± 7.19 and a median of -5.00 (-9.00 – 16.00) (Figure 1). Delta of the HOMA-IR control group was -1.41 ± 2.61 and a median of -2.49 (-3.11 – 6.30), while the intervention group with a mean of -1.36 ± 2.40 and median of -2.87 (-3.11 – 4.72) (Figure 2). Delta of the HOMA-B control group was 33.93 ± 85.46 % and a median of 22.19 (-156 – 173.39) %, while the intervention group with a mean of 85.30 ± 118.70 % and median of 40.90 (-72 – 354.76) % (Figure 3).

The results of changes (delta) of FBG and HOMA-B in the control group are better than the

Table 1. Basic Characteristics of Participants of the Study

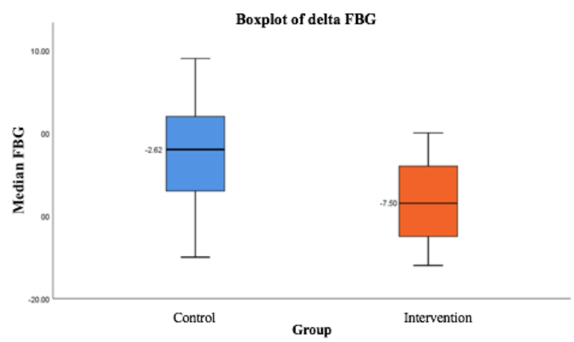
Characteristic	**Group**		**p-value**
	Control (White Rice)	**Treatment (Sorghum Rice)**	
Gender – n (%)			
Male	8 (61.5 %)	4 (33.3 %)	0.158
Female	5 (38.4 %)	8 (61.7 %)	
Age - Mean ± SD	33.83 ± 8.12	39.42 ± 5.68	0.061
Smoking – n (%)			
No	9 (69.2 %)	10 (83.3 %)	0.409
Yes	4 (30.7 %)	2 (16.6 %)	
Hypertension – n (%)			
No	11 (84.6 %)	11 (91.6 %)	0.588
Yes	2 (15.3 %)	1 (8.3 %)	
Systolic Blood Pressure (mmHg) Mean ± SD	120.77 ± 14.86	123.17 ± 12.13	0.664
Diastolic Blood Pressure (mmHg) Median (Range)	80 (71-106)	82 (70-100)	0.406
Dyslipidaemia – n (%)			
No	5 (38.4 %)	6 (50 %)	0.561
Yes	8 (61.5 %)	6 (0.9 %)	
Body Weight (kilogram) Mean ± SD	71.32 ± 12.89	70.60 ± 10.84	0.867
Body Mass Index Mean ± SD	27.38 ± 4.03	28.58 ± 4.65	0.500
Abdominal circumference (cm) Median (Range)	94 (67-103)	94 (68-101)	0.894
Fasting Blood Glucose (mg/dL) Median (Range)	102 (100-125)	104 (100-125)	0.769
Insulin - Mean ± SD	26.46 ± 9.36	27.42 ± 7.67	0.782
HOMA-B Median (Range)	180.2 (100.6-288.2)	184.3 (107.6-210.8)	0.247
HOMA-IR Mean ± SD	6.92 ± 2.55	7.20 ± 2.24	0.780
Total Calories	970.71 ± 44.29	961.45 ± 82.24	0.732
Carbohydrate - Median (Range)	132.35 (72.80-139.60)	125.00 (98.00-146.60)	0.574
Protein - Mean ± SD	44.58 ± 6.53	46.37 ± 9.25	0.584
Lipid - Mean ± SD	36.33 ± 5.09	34.41 ± 5.98	0.397
Cholesterol - Median (Range)	68.65 (46-301.80)	103.60 (18.40-556)	0.810
Fiber - Mean ± SD	9.40 ± 2.04	9.48 ± 1.97	0.850

Table 2. Changes in Fasting glucose, insulin, HOMA-IR, and HOMA-B before and after the intervention in the treatment group

Variable	Time	Min-Max	Median	Mean	SD
Fasting glucose	Pre	100 – 125	104	105.67	7.22
	Post	84 – 109	99	98.17	7.27
Insulin	Pre	17.68 – 39.16	29.02	27.42	7.67
	Post	13.40 – 43.30	19.13	23.86	11.01
HOMA-IR	Pre	4.36 – 10.82	7.40	7.20	2.24
	Post	2.90 – 10.47	4.53	5.84	2.75
HOMA-B	Pre	107.56 – 210.76	184.29	162.97	42.07
	Post	107.45 – 470.71	225.19	248.27	122.29

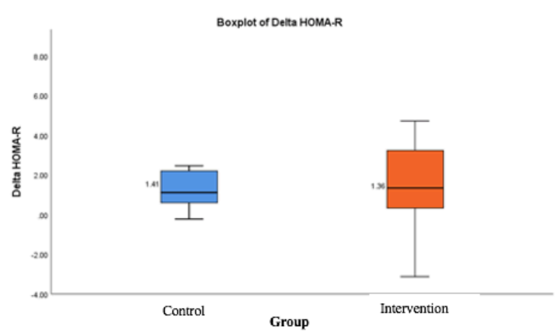
Table 3. The difference in Fasting glucose, HOMA-IR, and HOMA-B before and after intervention in the treatment group

Variable	Time	Median	Mean ± SD	Wilcoxon signed Rank test	
				Delta	p-value
Fasting glucose	Pre	104.00	105.67 ± 7.22	-7.5	0.014*
	Post	99.00	98.17 ± 7.27		
HOMA-IR	Pre	7.40	7.20 ± 2.24	-1.36	0.060
	Post	4.53	5.84 ± 2.75		
HOMA-B	Pre	184.29	162.97 ± 42.07	85.3	0.019*
	Post	225.19	248.27 ± 122.29		



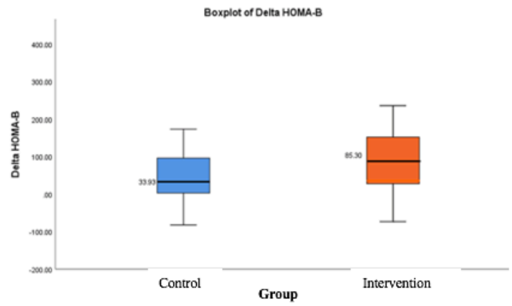
Delta FBG	n	Mean ± SD	Median (Min-Max)	p-value t-test
Control	13	-2.62 ± 6.89	-2.00 (-9.00 – 15.00)	0.096
Intervention	12	-7.50 ± 7.19	-5.00 (-9.00 – 16.00)	

Figure 1. Boxplot diagram of FBG delta comparison before and after intervention between control and treatment groups.



Delta HOMA-R	n	Mean ± SD	Median (Min-Max)	p-value t-test
Control	13	-1.41 ± 2.61	-2.49 (-3.11 – 6.30)	0.961
Intervention	12	-1.36 ± 2.40	-2.87 (-3.11 – 4.72)	

Figure 2. Boxplot diagram of delta HOMA-IR comparison before and after intervention between control and treatment groups.



Delta HOMA-B	n	Mean ± SD	Median (Min-Max)	p-value t-test
Control	13	33.93 ± 85.46	22.19 (-156 – 173.39)	0.224
Intervention	12	85.30 ± 118.70	40.90 (-72 – 354.76)	

Figure 3. Boxplot diagram of delta HOMA-B comparison before and after intervention between control and treatment groups.

intervention group, while the median of HOMA -IR delta is better for the intervention group, but the control group is better on its average. Furthermore, changes in FBG, HOMA-IR, and HOMA-B from the control group were compared with the intervention group. The distribution of changes (delta) of FBG, HOMA-IR, and HOMA-B data was normal, then tested by t-test, the results of which did not give a statistically significant difference for FBG, HOMA-IR, and HOMA-B.

DISCUSSION

The subjects in this study were people with prediabetes in accordance with the PERKENI criteria (12), where the prevalence in Indonesia continued to increase. The proportion of impaired fasting blood glucose by gender is more or less the same, namely 27.3 % for men and 25.3 % for women, while the proportion of impaired glucose tolerance suffered more by women (34.7 %) than men (26.8 %). In this study, the proportion of males compared to females was balanced, that is, of the 25 research subjects, 12 (42 %) were male and 13 were female (48 %), which were not statistically significantly different (p= 0.158) (Table 1) (14).

The prevalence of prediabetes increases with age as beta cell function and insulin sensitivity decrease. The International Diabetes Federation (IDF) in the IDF Atlas 9th Edition reports that the prevalence of impaired glucose tolerance increases with age, and reaches its peak in the 50-54 years age range which reaches around 42 million cases globally; and is predicted to continue to increase in 2030 and 2045, reaching 48 million and 62 million cases, respectively (3). In this study, the mean age of the 25 research subjects was 36.52 ± 7.47 years, while the mean age in the treatment group was 39.42 ± 5.68 years and in the control group 33.85 ± 8.12 years, where they were not statistically different (p=0.061) (Table 1).

Smoking habits can trigger inflammation that results in insulin resistance and increases blood glucose levels. The effect of smoking on prediabetes has been reported in several studies where in the group of active smokers, the risk of developing prediabetes increased 1.8-2.3 times compared to non-smokers. In a young male population, it was found that smoking also increases insulin resistance by decreasing glucose uptake (15). This is found in approximately 10 %-40 % of men who smoke (16,17). In this study, smoking habits in the treatment group (33.3 %) and control (66.7 %) were not significantly different (p=0.409) (Table 1).

Likewise, Systolic Blood Pressure values, the treatment sample had a higher mean of 123.17 mmHg compared to 120.77 mmHg. The Diastolic Blood Pressure values was also higher in the treatment group where the median value was 82 mmHg compared to 80 mmHg in the control group. P-values for systolic and diastolic blood pressure was 0.664 and 0.406, respectively, which indicates that the distribution of systolic and diastolic values of the research sample is also homogeneous (Table 1). Hypertension and dyslipidemia along with obesity causes insulin resistance and impaired blood glucose levels, increasing the risk of prediabetes and even diabetes. RISKESDAS data found that hypertension contributes to the onset of prediabetes, where the prevalence of prediabetes can be reduced to 56.5 % by preventing the occurrence of hypertension (14). Hypertension also has an important role in causing insulin resistance. Increased activation of the renin-angiotensin-aldosterone system (RAAS) will cause insulin resistance through stimulation of angiotensin II to type 1 receptor, which in turn will increase the production of reactive oxygen species (ROS) in adipocytes, striated muscle, and cardiovascular tissue (18,19). Otherwise, the condition of insulin resistance itself can also increase the risk of hypertension. This occurs through decreased production of endothelium-derived nitrous/nitric oxide. Activation of the sympathetic nerves and increased sodium reabsorption in the kidneys can also increase the incidence of insulin resistance (18). In this study, comorbid hypertension in the treatment group (33.3 %) and control (66.7 %) did not differ statistically (p=0.588) (Table 1).

Likewise, comorbid dyslipidemia in the treatment group (42.9 %) and control (57.1 %) did not differ significantly (p=0.561) (Table 1). Patients with insulin resistance usually show a decreased lipid profile in HDL as well as an increase in VLDL and LDL. Patients with insulin resistance have increased VLDL synthesis which will increase TG. This can occur in obese patients, non-obese, patients with type 2 diabetes mellitus, and even in healthy reported that sorghum supplementation for 90 days significantly reduced total and LDL cholesterol in 15 diabetic subjects, but did not significantly reduce HDL, VLDL, and TG cholesterol (20,21).

Several studies have shown that obesity, especially central obesity, is a strong predictor of the onset of prediabetes. The results of the RISKESDAS data analysis showed that prediabetes was significantly associated with obesity and central obesity; where obesity increases the risk of developing prediabetes by 1.2 times, while central obesity increases the risk of developing prediabetes by 1.5 times (14). In this study, the mean body mass index (BMI) for both the treatment and control groups was included in the WHO category of obesity (BMI > 27.0). The mean BMI of the treatment group was 28.58 ± 4.65 kg/m^2 and the mean BMI of the treatment group was 27.38 ± 4.03 kg/m^2, both of which were not statistically diferent (p=0.50). The weight characteristics of the two groups in this study were also not significantly different (p=0.867), where the mean weight of the treatment group was 70.60 ± 10.84 kg and the control group was 71.32 ± 12.89 kg. The median abdominal circumference measured in this study was found to be the same in both groups, namely 94 cm (Table 1).

In a randomized controlled trial, Anunciacao et al. reported that patients who consumed sorghum experienced significant weight loss, decreased abdominal circumference, hip-to-height ratio, and body fat percentage (22). This study is a clinical dietary intervention study where nutrition in both groups needs to be well controlled. The number of calories received by the treatment group from sorghum rice was 961.45 ± 82.24 kcal/day, while the control group received white rice with total calories of 970.71 ± 44.29 kcal/day, where both were not statistically different (p=0.732). The composition of carbohydrates, protein, fat, cholesterol and fiber from sorghum rice received by the treatment group and white rice received by the control group as a whole did not differ statistically (p=0.574, 0.584, 0.397, 0.810, and 0.850). From this data, it is expected that the treatment bias of the number of calories received between the two groups does not occur (Table 1).

The baseline glycemic profile before treatment in the two groups also did not show a significant difference. The range of FBG levels in the treatment group was 92-125 mg/dL (median = 104) statistically not different from the range of FBG values for the control group of 100-125 mg/dL (median = 102), where the p-value = 0.769. The mean insulin levels of the two groups were also not significantly different (p=0.782), where the mean insulin level in the treatment group was

27.42 ± 7.67 U/mL and the average insulin level in the control group was 26.46 ± 9.36 U/mL. The HOMA-B and HOMA-IR values obtained also did not show a significant difference between the two groups. The range of HOMA-B values for the treatment group was 107.6-210.8 (median = 184.3), while the range of HOMA-B values for the control group was 100.6–288.2 (median = 180.2), where p-value = 0.247. The mean HOMA-R-value for the treatment group was 7.20 ± 2.24, while the mean HOMA-IR-value for the control group was 6.92 ± 2.55, where p-value = 0.780 (Table 1).

Research on the effect of sorghum on FBG, HOMA-IR, and HOMA-B in prediabetes is still very limited. We did not find any research that had the same PICOS (Population, Intervention, Control, Outcome, and type of study). Clinical experimental research that is almost similar to this research is the study by Gu with 15 prediabetic men as research subjects. Gu conducted a sorghum cake intervention compared to a wheat cake control with a washout period of one week. What was measured were post-prandial blood glucose and insulin levels, namely at 15 minutes before (baseline), 0, 15, 30, 45, 60, 75, 90, 120, and 180 minutes after treatment in each group. This study concluded that the sorghum cake had a higher functional fiber content compared to the control; with the benefit of significantly lowering blood glucose and insulin levels at intervals of 45-120 minutes. The mean incremental area under curve (iAUC) blood glucose and insulin levels were significantly reduced by 35 % and 36.7 %, respectively (9).

Research with a longer period is the 2002 DPP in America, within 6 months it was found that there was a significant decrease in FBG and the incidence of DM in the group that underwent lifestyle intervention compared to the placebo group (23). In research conducted by Rachmawati et al. in Indonesia, giving sorghum cake for 28 days to obese subjects reduced FBG from 88.40±7.87 mg/dL to 82.40±4.03 mg/dL which was significant (24).

Most people with prediabetes are not aware that they have prediabetes. Early identification of prediabetes can proactively prevent progression to type 2 diabetes mellitus through diet control, physical activity, and lifestyle changes (25). A large study in China's Da Qing Diabetes Prevention Outcome Study, the Diabetes Prevention Program Research in America, the Japanese Diabetes Prevention Program in Japan, and the Indian Diabetes Program in India showed that lifestyle changes were proven to prevent the occurrence of DM2. Physical exercise and diet both acutely and chronically. combating glucose metabolism and insulin sensitivity (26).

This study compares the standard lifestyle intervention with the standard lifestyle intervention plus the substitution of white rice with sorghum rice. Compared to white rice which has a high GI of 74-82, sorghum rice has a low GI of 32. The glycemic load of sorghum rice (3.15-3.4 for brown sorghum rice and 4.6 for white sorghum rice) is much lower than that of white rice (20.5). The high content of resistant starch (up to 60 %) makes it difficult for rice sorghum to be enzymatically digested by the amylase enzyme during the first 120 minutes (27). This study found a significant difference in fasting blood sugar levels before and after the intervention, but this decrease (-7.50 ± 7.19) did not have a significant difference when compared to the control group (-2.62 ± 6.69; p> 0.05). Research conducted by Rachmawati et al. with a longer study period gave significant results (24). It may take a longer period to show a significant difference between the standard intervention and the standard intervention plus substitution with sorghum rice.

CONCLUSION

Standard lifestyle intervention plus diet substitution with sorghum rice for 7 days influences FBG and beta cell function in prediabetic patients but not on IR. The limitation of this study is that it did not evaluate glycated hemoglobin (HbA1c) and oral glucose tolerance test, and patients' activities, whereas it is also an important point for prediabetes monitoring.

Conflict of interest

The authors declare no conflict of interest.

Sponsor

The authors declare no sponsor is involved.

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