

## Effects of Sorghum Cookies (*Sorghum Bicolor L. Moench*) on Fasting Glucose, Triglyceride, High-Density Lipoprotein level, and Body Fat Percentage in Adolescent Obesity

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### ABSTRACT

**Background:** Adolescent obesity is related to the risk of metabolic syndrome. Several studies have proven the effect of dietary interventions on metabolic parameters in obese individuals. A source of complex carbohydrates that is still rarely developed in the obese diet is sorghum which contains resistant starch.

**Objective:** The study was to reveal the effect of sorghum cookies on Fasting Glucose (FG), Triglycerides (TG), High-Density Lipoprotein (HDL), and Body Fat Percentage (BFP) in obese adolescents.

**Materials and Methods:** This quasi-experiment with the pre-post control-group design was conducted on 20 boys and 20 girls (divided into 10-boy control group, 10-girl control group, 10-girl intervention group, and 10-girls intervention group) with the age range of 13–15 years who attended Junior High School 14 Semarang chosen by consecutive sampling. Weight, Height, and BFP were measured directly by BIA. Metabolic parameters (FG, TG, and HDL levels) were taken through venous and 10-hour fasting. Energy intake and physical activity were taken by interview using the food recall questionnaire for 6 days randomly and IPAQ. The intervention of sorghum cookies was given in 90 grams/day with 473 kcal/day for 28 days. The analysis of the effect of the intervention was conducted by a paired t-test and independent t-test.

**Results:** At 28-days sorghum cookies intervention resulted in lower levels of FG, TG, and BFP in the intervention boy group ( $p < 0.05$ ) and BFP in the girl group ( $p < 0.05$ ). The intervention of sorghum cookies showed no effect on HDL levels in boys, and it did not affect FG, TG, or HDL levels of the girl subjects ( $p > 0.05$ ).

**Conclusion:** Obese adolescents who had been receiving intervention of 90 grams of sorghum cookies for 28 days appeared to have lower levels of fasting glucose, triglycerides, and body fat percentage.

**Keywords:** Sorghum, Fasting Glucose, Triglycerides, HDL, Body Fat Percentage

### BACKGROUND

Adolescents are particularly susceptible to obesity due to various factors. The body's rapid growth and development necessitates more energy and nutrients. Changes in lifestyle and eating habits will have an impact on nutritional intakes, such as lack of fruits and vegetable intake and frequent intake of fatty and high sugar foods<sup>1</sup>. According to the data of Riskesdas 2018, the prevalence of obese adolescents in Indonesia has reached 16%. Central Java Province has a prevalence of obese adolescents of 11.19%, and Semarang City has a prevalence of obese adolescents of 11.09%.<sup>2</sup>

One type of Cerealia in intervention therapy for obesity is sorghum. Furthermore, sorghum is an alternative local food as it has a low glycemic index of 43 which is much lower than that of white rice of 82.<sup>3</sup> The low glycemic index is due to the contribution of high fiber content. Fiber can slow down the rate of food in the gastrointestinal tract and inhibit the activity of digestive enzymes so that it can control blood glucose.<sup>4</sup> Meanwhile, the mechanism of fiber in reducing fat absorption is by binding to fatty acids, cholesterol, and bile salt in the gastrointestinal tract. Fatty acids and cholesterol that are bound to fibers cannot form micelle which is needed for fat absorption to pass through unstirred water layers into enterocytes. As a result, the fat that binds to the fiber cannot be absorbed and will go to the large intestine to be removed with faeces or degraded

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by intestinal bacteria. In addition, fiber is also able to slow down gastric emptying and change gastric peristalsis, causing longer satiety so that appetite can be controlled.<sup>5</sup>

The food product that was administrated is sorghum cookies. The main ingredient of cookies is 60 g of sorghum flour processed with egg yolks, palm oil, glucose, flour, and skim milk. After it was baked, the total weight of the cookies was 90 g. Cookies were distributed in the morning, afternoon, and evening (3 times a day). Daily serving could replace 473 calories per day or 25% of total calories for boy adolescents and 30.5% for girl adolescents.<sup>6</sup>

Polysaccharides in sorghum are resistant starches that function as prebiotics. In 90 g of sorghum cookies, there is 2.43% of resistant starch. Processing cookies with heating and cooling can enhance resistant starch levels by up to 9%.<sup>7</sup> This starch is difficult to digest in the small intestine and to be fermented by bacteria in the large intestine. The fermentation results in the form of SCFA (Short-Chain Fatty Acid) act as a key regulator to modulate intestinal integrity, energy homeostasis, anti-inflammatory, control glycemic and insulin response, and improve blood lipid profile.<sup>8</sup> In the previous study, Olawole *et al.* showed that giving sorghum flour concentration to a cake could inhibit the activity of  $\alpha$ -amylase and  $\alpha$ -glucosidase which could reduce glucose levels.<sup>9</sup> According to Shen *et al.*, Sorghum resistant starch can inhibit the increase in triglycerides, cholesterol, LDL, and increase HDL levels in someone with metabolic fat disorders. This resistant starch cannot be digested in the small intestine and then fermented by bacteria in the large intestine. The fermentation product in the form of SCFA (Short Chain Fatty Acid) plays a role in reducing blood cholesterol and increasing the volume of faeces and changing the number of bacterial microbiota populations.<sup>10</sup> Therefore, the researchers examined the effect of sorghum cookies on fasting glucose, TG, HDL, and body fat percentage in obese adolescents.

## MATERIALS AND METHODS

The design of this study is a quasi-experiment with a pre-post control-group design. The study was conducted in October 2021 in Semarang City and has received ethical clearance from the Semarang State University (UNNES) Health Research Ethics Committee No. 153/EC/KEPK/2021. Sampling was carried out by non-probability sampling with a purposive sampling technique.<sup>11</sup> The minimum sample size was calculated by  $X1-X2 = 10.5$ ;  $Z\alpha + Z\beta = 2.92$ ;  $\alpha = 0.05$ , so the total subject in a group was 10, and the total in 4 groups was 40. The groups were divided into a 10-boy control group, 10-girl control group, 10-girl intervention group, and 10-girls intervention group. Inclusion criteria included adolescents aged 13–15 years, having Z-score BMI/Age  $\geq 2SD$ , not consuming diet supplements or drugs, having no history of degenerative diseases, and being willing to fill in informed consent. Exclusion criteria included quitting during the study.

Data retrieval was conducted during the Covid-19 pandemic so that it obeyed the health protocol. The researchers and enumerators in charge of data retrieval wore masks and always washed their hands with soap before and after collecting the data from each subject. The subjects were also required to wear masks and use hand sanitisers. Anthropometry tools were cleaned using 70% alcohol at each subject change. Height data were measured using GEA microtoice with 0.1 cm accuracy, body weight was measured using Omron digital scale with 0.01 kg accuracy, and per cent body fat was measured using Bioimpedance Analysis (BIA, *Omron Karada HBF-375*) with 0.1% accuracy. The independent variable in this study was the intervention of sorghum cookies as much as 90 grams per day given as morning, afternoon, and evening snacks. The nutrient contents of sorghum cookies are listed in Table 1.

**Table 1. Nutrient Content of Sorghum Cookies**

Ingredient	Total (gr)	Energy (ca	Protein (gr	Fat (gr)	Carbohydrate (g	Fiber (gr)
Sorghum flour	60	199.2	6.2	1.8	44.2	7.6
Wheat flour	10	36.4	1.0	0.1	7.6	0.3
Palm oil	12	103.4	0	12	0	0
Egg yolk	10	27.8	1.9	2.1	0.2	0
Skimmed milk powder	10	36.8	3.6	0.2	5.2	0
Sugar	18	69.7	0	0	18	0
<b>Total</b>		<b>473</b>	<b>12.7</b>	<b>16.2</b>	<b>75.2</b>	<b>7.9</b>

Source: Center for Food and Nutrition Laboratory Gajah Mada University

Metabolic parameters were taken through vein blood vessels with 10-hour fasting. The blood specimen analysis was conducted at Diponegoro National Hospital Laboratory. FG levels are high if they are  $\geq 110$  mg/dl.<sup>12</sup> Triglyceride levels are high when they are  $\geq 150$  mg/dl, and HDL levels are low for boys when they

are < 45mg/dl; whereas, HDL levels are low for girls if they are < 50 mg/dl.<sup>12</sup> Percent of body fat was measured by the position of the subject rising to the top of the foot unit (without any footwear) attached to the leg electrodes. The hands were stretched forward to form an angle of 90° standing upright holding the hand electrode using the BIA Omron Karada HBF-375. The high BFP category for boys is ≥ 25%, for girls ≥ 30%.<sup>12</sup> The confounding variables in this study included gender, energy intake, and physical activity. Gender is a biological difference between boys and girls. Energy intake is the number of calories consumed from all types of food and drinks. Intake data were taken through 6-time interviews in 6 intermittent days with a food recall questionnaire and processed with Nutrisurvey using Windows software. Physical activity is a body movement that results in energy expenditure. The intervention of physical activity was jogging and skipping 5 times a week. Data on physical activity were taken through interviews on physical activity during the last 7 days using the International Physical Activity Questionnaire (IPAQ) instrument. IPAQ consists of 7 questions including the type, frequency, and duration.<sup>13</sup>

The data analysis using SPSS 23.0 computer software included univariate analysis, paired test (paired t-test), and unpaired different test (independent t-test). The univariate analysis looked at the distribution and normality of the data using the Shapiro Wilk test. Paired difference test aims to see the difference before and after intervention in each group on FG, TG, HDL, and BFP using paired t-test if the data are normally distributed, and the Wilcoxon test is used if the data are not normally distributed. Unpaired difference test aims to see differences in the results of FG, TG, HDL, and BFP between groups using the independent t-test if the data are normally distributed, and the Mann Whitney test is used if the data are not normally distributed.<sup>14</sup>

## RESULTS

### Subject Characteristics

A total of 40 subjects who met the inclusion criteria in the age range of 13–15 years were evenly divided into 4 groups, namely the boy and girl in the control group, boy and girl in the intervention group. The mean values (±SD) of the subjects was shown in Table 2.

Table 2. The Baseline Characteristics of Subjects

Variables	Boys		Girls	
	Control (n=10)	Intervention (n=10)	Control (n=10)	Intervention (n=10)
Body Weight (kg)	85.21±12.87	85.83±13.76	75.86±8.87	76.15±9.12
Z-score (SD)	2.96±0.44	2.98±0.47	2.45±0.29	2.48±0.24
Energy Intake (kcal)	2,454.50±39.90	2,460.50±35.31	2,092±308.58	2,147.50±27,40
Physical Activity (METs)	367.60±80.64	362.40±91.50	435.20±52.53	443.20±61.66
Fasting Glucose (mg/dl)	87.30±6.21	88.40±7.47	86.70±9.60	89.50±10.90
Triglyceride (mg/dl)	133.60±33.96	130.50±38.75	151.30±26.83	148.00±27.83
HDL (mg/dl)	38.20±7.44	38.60±10.07	39.90±4.36	42.10±5.94
Body Fat Percentage (%)	33.43±2.92	32.96±3.09	33.43±1.86	32.90±3.00

Table 2 showed the overall characteristics of the subjects by gender. Body weights in the boy group were higher than in the girl group. Z-Score increased simultaneously with energy intake. Low physical activity was found in both groups. Although the participants were mildly obese, they did not have impaired fasting glucose and TG but were low in HDL levels. A high body fat percentage was found in boys and girls.

### Differences in Body Weight (BW) between Pre- and Post-Interventions

Based on the Wilcoxon test, the boy control group showed no difference in the results of pre- and post-interventions (p = 0.443). In the boy intervention group, there was a significant difference (p= 0.005) with a decrease in BW (Δ) of 2.47±1.03 kg. Mann-Whitney test in the boy control and intervention groups showed no differences (p = 0.450) as shown in Table 3.

Table 3. Body Weights of Boy and Girl Groups

Groups	Boys			Girls		
	Pre(Mean±SD)	Post(Mean±SD)	p	Pre (Mean±SD)	Post(Mean±SD)	p
Control	80.05±13.57	80.05±13.23	0.443	75.86±9.35	75.71±9.17	0.288
Intervention	80.60±14.50	77.70±14.01	0.005*	76.15±9.61	73.68±9.82	0.001*
p <sup>1</sup>		0.450			0.639	

$p$  = Analyzed by Wilcoxon test

$p^1$  = Analyzed by Mann-Whitney test

\* =  $p < 0.05$  (significant)

Changes in body weight in the girl control group based on the paired test showed no different results between pre- and post-interventions ( $p = 0.288$ ). Meanwhile, the intervention group showed a significant difference ( $p = 0.001$ ) with a decrease in BW ( $\Delta$ ) of  $2.47 \pm 0.77$  kg. The Mann-Whitney test showed no significant BW difference between the girl control and intervention groups ( $p = 0.639$ ).

### Differences in Z-scores of BMI/Ages between Pre- and Post-Interventions

The Wilcoxon test results for the Z-score BMI/Age value in the boy control group showed no difference between pre- and post-intervention ( $p = 0.234$ ). Meanwhile, the intervention group showed a significant difference ( $p = 0.005$ ) with a decrease of ( $\Delta$ ) Z-Score BMI/Age of  $0.13 \text{ SD} \pm 0.04 \text{ kg/m}^2$ . According to the Mann-Whitney test, there was no difference in the BMI/Age Z-scores between the boy control and intervention groups ( $p = 0.496$ ) as shown in Table 4.

**Table 4. Changes of Z-Score in Boy and Girl Groups**

Groups	Boys			Girls		
	Pre(Mean±SD)	Post(Mean±SD)	$p$	Pre (Mean±SD)	Post(Mean±SD)	$p$
Control	2,845±0.46	2.840±0.45	0.234	2.45±0.30	2.44±0.31	0.247
Intervention	2.76±0.49	2.65±0.48	0.005*	2.48±0.25	2.36±0.27	0.001*
$p^1$		0.496			0.546	

$p$  = Analyzed by Wilcoxon test

$p^1$  = Analyzed by Mann-Whitney test

\* =  $p$  value  $< 0.05$  (significant)

The results of the Wilcoxon test in the girl control group showed no difference between pre- and post-interventions ( $p = 0.247$ ). The girl intervention group showed a significant difference ( $p = 0.001$ ) with a decrease in Z-Score of BMI/Age of  $0.12 \pm 0.05 \text{ kg/m}^2$ . Based on the Mann-Whitney test, there was no difference in the Z-scores between the girl control and intervention groups ( $p = 0.546$ ) as shown in Table 4.

### Differences in Energy Intakes (EI) between Pre- and Post-Interventions

Wilcoxon test results in the boy control group showed significant differences between pre- and post-interventions ( $p = 0.007$ ). For the intervention group, there was a significant difference ( $p = 0.005$ ) with a decrease ( $\Delta$ ) of per day energy of  $558 \pm 76.41$  kcal. According to the Mann-Whitney test, there were significant differences between the boy control and intervention groups ( $p = 0.001$ ) as contained in Table 5.

**Table 5. Changes in Energy Intake in Boy and Girl Groups**

Groups	Boys			Girls		
	Pre(Mean±SD)	Post(Mean±SD)	$p$	Pre(Mean±SD)	Post (Mean±SD)	$p$
Control	2450,00±42,00	2325,00±100.50	0.007*	2167.50±325,00	2150,00±127.64	0.332
Intervention	2460,00±37.22	1910,00±79.38	0.005*	2150,00±28.89	1562.50±35.74	0.005*
$p^1$		0.001*			0,001*	

$p$  = Analyzed by Wilcoxon test

$p^1$  = Analyzed by Mann-Whitney test

\* =  $p$  value  $< 0.05$  (significant)

The girl group, based on the results of the control group's Wilcoxon test, showed no difference between pre- and post-interventions ( $p = 0.332$ ). The intervention group showed a significant difference ( $p = 0.005$ ) with a decrease ( $\Delta$ ) of per day energy of  $587.5 \pm 52.45$  kcal. Based on the Mann-Whitney test, there were significant differences between the girl control and intervention groups ( $p = 0.001$ ) as contained in Table 5.

### Differences in Physical Activities (PA) between Pre- and Post-Interventions

Wilcoxon test results in the boy control group showed no difference between pre- and post-interventions ( $p = 0.284$ ). The boy intervention group showed a significant difference ( $p = 0.005$ ) with an increase in IPAQ scores ( $\Delta$ ) of  $271.1 \pm 81.63$  METs. Based on the Mann-Whitney test, there were significant differences between the boy control and intervention groups ( $p = 0.001$ ) contained in Table 6.

**Table 6. Changes in Physical Activity in Boy and Girl Groups**

Groups	Boys			Girls		
	Pre (Mean±SD)	Post (Mean±SD)	$p$	Pre (Mean±SD)	Post (Mean±SD)	$p$
Control	372.50±85.00	390,00±87.36	0.284	420,00±55.36	457.50±70.31	0.066
Intervention	360.50±96.45	631.50±25.17	0.005*	446.50±65.00	651.50±25.92	0.005*
$p^1$		0.001*			0,001*	

$p$  = Analyzed by Wilcoxon test

$p^l$  = Analyzed by Mann-Whitney test  
 \* =  $p$  value < 0.05 (significant)

The results of the Wilcoxon test in the girl control group showed no difference between pre- and post-interventions ( $p = 0.066$ ). The girl intervention group showed a significant difference ( $p = 0.005$ ) with an increase in AF ( $\Delta$ ) scores of  $203.7 \pm 44.46$  METs. Based on the Mann-Whitney test, there was a significant difference in the AF values between the girl control and intervention groups ( $p = 0.001$ ) as shown in Table 6.

**Differences in Fasting Glucose (FG) between Pre- and Post-Interventions**

The results of the paired t-test test in the boy control group showed no difference between pre- and post-interventions ( $p = 0.84$ ). This is in contrast with the intervention group that had a significant difference ( $p = 0.004$ ). Based on the independent t-test, there were significant differences in FG levels between the boy control and intervention groups ( $p = 0.045$ ) as shown in Table 7.

**Table 7. Changes in Fasting Glucose (FG) in Boy and Girl Groups**

Groups	Boys			Girls		
	Pre (Mean±SD)	Post (Mean±SD)	$p$	Pre (Mean±SD)	Post (Mean±SD)	$p$
Control	87.30±6.54	87.10±5.52	0.840	86.70±10.13	85.90±8.19	0.380
Intervention	88.40±7.87	82.40±4.03	0.004*	89.50±11.49	81.70±5.01	0.008*
$p^l$		0.045*			0.187	

$p$  = Analyzed by Paired T-Test  
 $p^l$  = Analyzed by Independent T-Test  
 \* =  $p$  value < 0.05 (significant)

The results of the paired t-test test on the girl control group showed no difference between pre- and post-interventions ( $p = 0.38$ ). It is different from the girl intervention group which showed a significant difference ( $p = 0.008$ ). Based on the independent t-test analysis, there was no significant difference in FG levels between the girl control and intervention groups ( $p = 0.187$ ) as shown in Table 7.

**Differences in TG Levels between Pre- and Post-Interventions**

The results of the paired t-test test in the boy control group showed no difference between pre- and post-interventions ( $p = 0.052$ ). This is in contrast with the intervention group that had a significant difference ( $p = 0.005$ ). Based on the independent t-test, there were significant differences in TG levels between the boy control and intervention groups ( $p = 0.013$ ) as shown in Table 8.

**Table 8. Changes in Triglyceride Levels in Boy and Girl Groups**

Groups	Boys			Girls		
	Pre (Mean±SD)	Post (Mean±SD)	$p$	Pre (Mean±SD)	Post (Mean±SD)	$p$
Control	121.50±35.79	127.50±30.37	0.052	151.30±28.28	150.20±22.99	0.682
Intervention	114.50±40.85	91.00±41.90	0.005*	148.00±29.33	126.20±30.78	0.001*
$p^l$		0.013*			0.064	

$p$  = Analyzed by Wilcoxon test  
 $p^l$  = Analyzed by Mann-Whitney test  
 \* =  $p$  value < 0.05 (significant)

Based on the paired t-test analysis, the girl control group showed no difference between pre- and post-interventions ( $p = 0.682$ ). It is different from the girl intervention group which showed a significant difference ( $p = 0.001$ ). Based on the independent t-test, there was no significant difference in TG levels between the girl control and intervention groups ( $p = 0.064$ ) as shown in Table 8.

**Differences in HDL Levels of Pre- and Post-Intervention**

The results of the paired t-test analysis on the boy control and intervention groups showed no difference between pre- and post-interventions ( $p = 0.664$ ;  $p = 0.089$ ). Based on the independent t-test, there was no difference between the two boy groups ( $p = 0.505$ ) as shown in Table 9.

**Table 9. Changes in HDL Levels in Boy and Girl Groups**

Groups	Boys			Girls		
	Pre (Mean±SD)	Post (Mean±SD)	$p$	Pre (Mean±SD)	Post (Mean±SD)	$p$
Control	38.20±7.84	37.90±6.50	0.664	39.90±4.60	37.90±4.09	0.060
Intervention	38.60±10.61	35.90±6.64	0.089	42.10±6.26	38.40±3.34	0.012*
$p^l$		0.505			0.768	

$p$  = Analyzed by Paired T-Test  
 $p^l$  = Analyzed by Independent T-Test  
 \* =  $p$  value < 0.05 (significant)

The girl control group, based on the paired t-test analysis, showed no difference between pre- and post-interventions ( $p = 0.060$ ). Meanwhile, the girl intervention group showed a significant difference ( $p = 0.012$ ). Based on the independent t-test analysis, there was no difference in HDL levels between the girl control and intervention groups ( $p = 0.768$ ) as shown in Table 9.

### Differences in Body Fat Percentage (BFP) between Pre- and Post-Interventions

Paired t-test analysis results in the boy control group showed no difference between pre- and post-interventions ( $p = 0.882$ ). The intervention group showed a significant difference ( $p = 0.001$ ). Based on the independent t-test analysis, there were significant differences in BFP between the boy control and intervention groups after the intervention of sorghum cookies ( $p = 0.001$ ) as shown in Table 10.

**Table 10. Changes in Body Fat Percentage (BFP) in Boy and Girl Groups**

Groups	Boys			Girls		
	Pre (Mean±SD)	Post (Mean±SI)	<i>p</i>	Pre (Mean±SD)	Post (Mean±SD)	<i>p</i>
Control	33.43±3.08	33.37±2.41	0.882	33.43±1.96	33.17±1.96	0.166
Intervention	32.96±3.26	27.31±3.19	0.001*	32.90±3.17	28.52±2.70	0.001*
<i>p</i> <sup>1</sup>		0.001*			0.001*	

*p* = Analyzed by Paired T-Test

*p*<sup>1</sup> = Analyzed by Independent T-Test

\* = *p* value < 0.05 (significant)

The girl control group, based on the paired t-test analysis, had no difference between pre- and post-interventions ( $p = 0.166$ ). It is different from the girl intervention group which showed a significant difference ( $p = 0.001$ ). The independent t-test analysis showed a significant difference in the values of BFP between the girl control and intervention groups ( $p = 0.001$ ) as shown in Table 10.

## DISCUSSION

This study observed the effect of the difference in the intervention of 90 grams of sorghum cookies for consecutive 28 days on fasting glucose (FG), Triglyceride (TG), HDL, and Body Fat Percentage (BFP) on obese adolescents. It was found that the intervention of sorghum cookies could reduce FG, TG, and BFP in the boy group, and it reduced BFP in the girl group ( $p < 0.05$ ). Before the treatment, both groups were homogeneous, so the change in all parameters values was due to the sorghum intervention.

The intervention of sorghum cookies could decrease the bodyweight of both intervention groups because sorghum cookies contain 7.9 g of fiber and 2.43 g of resistant starch. They are used as a snack with low calories but contain soluble and insoluble fibers with a longer satiety effect so that weight loss can slowly be achieved. Fiber cannot be absorbed in the small intestine and would absorb water and form a gel in the stomach. Fiber could prolong transit time in the stomach and felt full longer.<sup>10</sup> In addition, the influencing factor was the addition of physical activity with jogging and skipping.

Z-scores of BMI/age parameter decreased after intervention in the treatment group. It was because the Z-scores decreased simultaneously with weight loss. It caused decreasing body fat and more energy expenditure. There were significant differences in energy intakes in both boy and girl groups ( $p = 0.001$ ;  $p = 0.001$ ) to reduce energy in the intervention group by 500 calories/day. This is under the recommendation of a maximum weight loss of 2 kg/month or 500 g/week by reducing energy intake to 500 kcal/day.<sup>15</sup>

Differences were observed in the physical activity of the intervention group derived from the physical activity program for 150 minutes/week. Jogging for 25 minutes and skipping for 5 minutes were done regularly 5 times a week. The physical activity aims to create a balance between the energy obtained and the energy released by the body. For obese adolescents, this creates a negative energy balance that can lose weight.<sup>16</sup> Physical activity that could increase energy export meets the criteria of frequency, intensity, type, and duration. Physical activity has a frequency in how often the activity is conducted. Usually, the frequency of training in the week ranges from 3 to 5 times and depends on the individual condition. The intensity was how hard an activity was conducted. It was usually classified into low, medium, and high intensity. In the initial stages, it should be done with moderate intensity (64–76% of the maximal heart rate) and increased as time goes by. Time refers to how long activity was conducted in one meeting. Usually, the intensity was 30–60 minutes for each exercise. Types of activities refer to the types of physical activities carried out such as walking, jogging, biking, swimming, and so on.<sup>17</sup>

Differences in FG levels after intervention in the boy group were influenced by the content of sorghum including soluble fiber and resistant starch. Resistance starch makes a lower sorghum glycemic index than

rice. Resistant starch cannot be absorbed by digestive enzymes, and resistant starch metabolic processes occur 5–7 hours after consumption. Hence, the water-soluble fiber contained in sorghum will absorb water and form a gel in the stomach that can extend gastric emptying.<sup>7</sup> Fermentation occurs in the large intestine that produces Short-Chain Fatty Acid (SCFA). As a result, these fatty acids will return to the bloodstream and could inhibit the use of glucose by body tissues for a long time, thereby increasing peripheral insulin sensitivity. It causes a decrease in blood glucose levels and improvement of insulin resistance. This finding is in line with previous research that sorghum flour can reduce fasting glucose and improve insulin sensitivity ( $p \leq 0.05$ ).<sup>4</sup>

There was a difference in TG levels between the boy control and intervention groups after the intervention ( $p = 0.013$ ), but there was no difference in the girl groups ( $p = 0.064$ ). The decrement in TG levels due to the presence of starch content in sorghum acts as a prebiotic that induces changes in intestinal microbiota. Resistant starch that cannot be digested in the colon will be fermented to produce SCFA. SCFA production will encourage the expression of pro-glucagon and increase the production of Glucagon Like Peptide-1 (GLP 1). GLP 1 was known as an intestinal hormone secreted by L ileum cells and suppresses hepatic lipogenesis through activation of the Adenosine Monophosphate Protein Kinase (AMPK) pathway.<sup>18</sup> AMPK is an energy metabolism regulatory enzyme that works by inhibiting the pathway of anabolism and stimulating the path of catabolism (metabolic homeostasis). Activation of the AMPK pathway that can reduce hepatic lipogenesis can reduce serum triglyceride levels. Based on previous studies, sorghum flour can reduce the number of adipose cells that express Peroxisome Proliferators-Activated Receptors (PPAR- $\gamma$ ). PPAR- $\gamma$  plays a role in the storage of fatty acids in adipose cells.<sup>19</sup>

There are no differences in HDL levels between the control and intervention groups in boys and girls after the intervention ( $p = 0.505$ ;  $p = 0.768$ ). This is estimated because the effects of dietary foods can affect HDL levels requiring 6–8 weeks.<sup>20</sup> The importance of increasing HDL-c cholesterol in a person with obesity is because HDL-c cholesterol functions to bring excess cholesterol into blood vessels and transport it to the liver for further metabolism. Improved HDL-c can be done by increasing physical exercise with the principle of FITT (frequency, intensity, type, time). Improved HDL-c by increasing physical exercise with the FITT principle requires 3 to 6 months.<sup>20</sup>

Differences in BFP changes based on the independent t-test between the control and intervention groups of boy and girl adolescents ( $p = 0.001$ ). A decrease in BFP caused by the consumption of sorghum cookies for 28 days can increase the intake of complex carbohydrates and fibers and reduce body fat in someone with obesity. This is similar to previous studies of the correlation of intervention of 40 grams of sorghum per day in 8 weeks to decrease body fat ( $p \leq 0.05$ ).<sup>21</sup> Another study found that a low-calorie diet in the second week could decrease fat by 50–70% due to fatty acid oxidation.<sup>22</sup>

## CONCLUSION

The intervention of 90 g/day of sorghum cookies for 28 days reduces fasting blood glucose, triglycerides, and percent body fat in the boy group, and it reduces percent body fat in the girl group ( $p < 0.05$ ).

## SUGGESTION

Additional duration of dietary intervention and physical activity is needed as it will affect HDL level changes which need 3–6 months.

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