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The Effect of Low and High Glycemic Load Diet on Muscle Fatigue of Young Soccer Athletes

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Abstract. Muscle fatigue in adolescent soccer athletes can degrade performance during a match. A low glycemic load (GL) diet before exercise is believed to improve soccer athlete performance because it can decrease carbohydrate oxidation during exercise and has a lower increase in lactic acid levels than a high GL diet. The study aimed to identify the effect of low and high glycemic load diets on muscle fatigue in adolescent soccer athletes. A quasi experimental pre-post group design was conducted on 22 adolescent soccer athletes aged 15-17 at the Terang Bangsa Soccer School Semarang. The low GL group was given food with GL 9.15; while the high GL group contained GL 27.29. Diets given once in 2 hours before exercise. Each group was triggered RAST (Running based Anaerobic Sprint Test) to cause anaerobic muscle fatigue. Muscle fatigue is measured using blood lactic acid, BUN (Blood Urea Nitrogen), and fatigue index. There were no significant differences in blood glucose, lactic acid, and BUN levels between low GL and high GL groups ($p>0.05$). Nonetheless, a low GL diet had a smaller increase in blood glucose levels (1.91 mg/dL vs 4.09 mg/dL) and lactic acid (4.5 mg/dL vs 4.7 mg/dL) after exercise than high BG diet. A low GL diet also has a lower fatigue index than a high GL.

Abstrak. Kelelahan otot pada atlet sepakbola remaja dapat menurunkan performa selama pertandingan. Diet rendah glikemik (BG) sebelum latihan diyakini dapat meningkatkan kinerja atlet sepak bola karena dapat menurunkan oksidasi karbohidrat selama latihan dan memiliki peningkatan kadar asam laktat yang lebih rendah daripada diet BG tinggi. Penelitian ini bertujuan untuk mengidentifikasi pengaruh diet beban glikemik rendah dan tinggi terhadap kelelahan otot pada atlet sepak bola remaja. Penelitian quasi experimental pre-post group design dilakukan pada 22 atlet sepakbola remaja berusia 15-17 di Sekolah Sepak Bola Terang Bangsa Semarang. Kelompok BG rendah diberi makanan dengan gl 9,15; sedangkan kelompok BG tinggi mengandung gl 27,29. Diet diberikan sekali 2 jam sebelum latihan. Setiap kelompok dipicu oleh RAST (Running Based Anaerobic Sprint Test) untuk menyebabkan kelelahan otot anaerobik. Kelelahan otot diukur menggunakan asam laktat darah, BUN (Blood Urea Nitrogen), dan indeks kelelahan. Tidak ada perbedaan yang signifikan pada kadar glukosa darah, asam laktat, dan BUN antara kelompok rendah dan BG tinggi ($p>0,05$). Meski demikian, diet BG rendah memiliki peningkatan kadar glukosa darah (1,91 mg/dl vs 4,09 mg/dl) dan asam laktat (4,5 mg/dl vs 4,7 mg/dl) setelah berolahraga yang lebih kecil daripada diet bg tinggi. Diet BG rendah juga memiliki indeks kelelahan yang lebih rendah daripada BG tinggi.

INTRODUCTION

There has been a decline in achievement on the Indonesian U-19 national soccer team. In 2013, the U-19 national team won the AFF (ASEAN Football Federation) trophy. However, in 2018 the U-19 national team failed to pass the

quarter-finals at the ASIA Cup. A study by the Indonesian Football Association National Team (PSSI) showed that Indonesian professional soccer athletes often got fatigue and decreased performance especially starting in the 60th minute (Setiawan 2018). Muscle fatigue occurs when the supply of ATP (Adenosine Triphosphate) fails to meet ATP consumption during exercise. This occurs because the supply of oxygen to the cells is inadequate so that the ATP production process shifts from the aerobic process (with oxygen) to anaerobic glycolysis (without oxygen), resulting in the accumulation of lactate in the blood (Wan et al. 2017).

When the anaerobic glycolysis occurred, AMP (Adenosine Monophosphate) molecules are formed to maintain the ATP/ADP (Adenosine Triphosphate/Adenosine Diphosphate) ratio. Then AMP is degraded by AMP-deaminase to IMP (Inosine Monophosphate) and ammonia. Ammonia is converted to blood urea nitrogen (BUN), so that in anaerobic conditions an increase in BUN levels will occur (Wan et al. 2017). The worse the body's adaptation to tolerate exercise, the more significantly the level of urea nitrogen increases. Therefore, BUN is another index of fatigue status besides lactic acid (Jin & Wei 2011; Ding et al. 2011).

A low glycemic index (GI) carbohydrate consumption mentioned more appropriate given before the endurance exercise plan than high GI foods. Low GI foods can increase blood glucose more slowly so that blood glucose becomes more stable than high GI foods (Ghiasvand et al. 2015; Cocate et al. 2011). It causes a blood glucose homeostasis, decreased carbohydrate oxidation and increased fat oxidation which can reduce lactic acid levels (Chen et al. 2008). The glycemic index of carbohydrates only describes the type of carbohydrate, without considering the total amount of carbohydrates contained in food. Meanwhile, not only the type of carbohydrate, but the amount of carbohydrate also affects postprandial glycemic and insulin responses which will have an impact on muscle glycogen supply and athlete performance (Reilly et al. 2010).

The GI concept is perfected by the glycemic load. Glycemic load (GL) is the result of the amount of carbohydrates (grams) with food GI divided by 100. Glycemic load provides more complete information about the effect of carbohydrate food consumption on increasing blood glucose levels and can estimate the impact of a number of carbohydrates and GI on blood glucose concentration in the same time (Reilly et al. 2010).

A recent studies suggest that a low GL diet 3 hours before exercise can induce glycogen concentrations, free fatty acids, higher fatty acid oxidation and lower carbohydrate oxidation, simultaneously, during the postprandial period and during exercise (Ghiasvand et al. 2015; Chen et al. 2008). The increase in blood glucose in the low-GI low-GL (L-L) diet group occurred slowly compared to the low GI high GL (L-H) and high-GI high GL (H-H) group (Siwi et al. 2017). In addition, the increase in lactate levels after exercise was lower in the low GL (L-L and H-L) group compared to the high IG high GL (H-H) group (Chen et al. 2008). Increased fatty acid oxidation and decreased carbohydrate oxidation as a result of low carbohydrate GL intake, causing a decrease in anaerobic glycolytic activity and accumulation of blood lactic acid (Achten & Jeukendrup 2004).

This study aims to analyze the differences in the effect of giving low and high glycemic load diets 2 hours before training on muscle fatigue of teenage soccer athletes characterized by levels of lactic acid, BUN, and fatigue index.

METHOD

This research is a quasi experimental pre-posttest group design with 2 treatment groups. The study was conducted at the Terang Bangsa Semarang Football School (SSB) with 11 research subjects in each group. Subjects were randomly divided into two groups consisting of low GL group and high GL group. The subjects were selected through simple random sampling. The inclusion subject criteria: (1) men aged 15-18 years, (2) joined in soccer clubs for at least 1 year, (3) a minimum of 90% physical exercise attended in the last 12 weeks, (4) not being sick, injured, or in the care of a doctor, (5) not taking carbohydrate-based supplements or sports drinks in 24 hours before the study, (6) not doing high intensity physical exercise in 24 hours before the study, (7) not smoking and consuming alcohol.

The low GL group was given carbohydrate-source foods with a glycemic load of 9.15, while the high GL group was given carbohydrate-source foods with a glycemic load of 27.29 (Table 1). Food is given once at 2 hours before training. Subjects were fasted 10 hours before the intervention.

TABLE 1. Nutritional Composition of Pre-exercise Meals

Meal	Contents	Nutrition Analysis	Estimated mix GI	Estimated mix GL
6 Low GL (Low GI Low GL/L-L)	Boiled spaghetti (90 g)	400.18 kkal	31.79	9.15
	Scramble egg (50 g)	28.77 g CHO (30%)		
	Cornet beef (25 g)	20.66 g fat (46%)		
	Palm oil (10 g)	23.56 g protein (24%)		
	Boiled corn (100 g)	391.53 kkal		
High GL (Medium GI High GL/M-H)	Sweetened condensed milk (40 g)	45.586 g CHO (47%)	59.86	27.29
	Cheddar kraft cheese (20 g)	19.47 g fat (45%)		
	Butter (10 g)	9.09 g protein (8%)		

Note. GI value and GL were calculated by a method described in (Rimbawan & Siagian 2004)

The data collection includes the subject's characteristics which are name, age, and date of birth taken using questionnaires. Weight, height, body fat percent, and muscle mass percent data were measured before giving intervention using the Bioelectric Impedance Analyzer (BIA). Data on physical activity and sleep duration of the last 24 hours were measured using the Physical Activity Log (PAL) form. Data of the last 24-hour meal intake was measured using a 24-hour recall form. VO₂max data was measured using a bleep test.

Blood glucose levels were measured using a glucometer and blood lactic acid levels with Accutrend Plus Brand Roche. Hemoglobin levels were measured using cyanhemoglobin method. BUN levels were measured using the colorimetric method with a photometer or chemical analyzer. Blood glucose, lactic acid, BUN levels were measured 3 times, those are before the intervention, immediately after the RAST exercise test, and 1 hour after exercise. The fatigue index is measured using the RAST (The Running based Anaerobic Sprint Test) method. Subjects asked to run sprints on a 35.17 meter straight track with a maximum speed of six times with a 10-second pause between each repetition. The fatigue index is calculated by the formula (maximum power output - minimum power output) ÷ total time for six sprints.

The data of fatigue index, lactic acid and BUN levels before intervention, immediately after exercise, 1 hour after exercise (recovery period), and subject characteristics between the two groups were examined using the independent-t-test and Mann-Whitney test. Multivariate tests were performed if there were different in subject characteristics data between the two groups using general linier model (GLM) repeated measures.

RESULT AND DISCUSSION

The study was conducted in 22 adolescent soccer athletes with an average age of 16 years. Data on the subject's characteristics showed no significant differences in age, Body Mass Index (BMI), fat mass percent, VO₂max, hydration status, hemoglobin levels, physical activity, and sleep duration between the two groups ($p > 0.05$) (Table 7). Only percent of muscle mass showed a difference between the two groups ($p < 0.05$). However, the mean VO₂max, hydration status, hemoglobin level, and sleep duration in the low BG group were higher than the high BG group.

TABLE 1. Subject Characteristics in Both of Groups

Variable	Low GL (n=11)			High GL (n=11)			p
	Mean±SD	Min	Max	Mean±SD	Min	Max	
Age (years)	16±0.77	15	17	15.91±0.83	15	17	0.78 ^b
BMI (kg/m ²)	21.02±1.64	18.40	23.50	22.84±2.49	19.10	26.30	0.06 ^a
Fat mass percent (%)	15.96±2.53	12.00	19.60	18.31±3.56	13.90	23.10	0.09 ^a
Muscle mass percent (%)	41.92±1.93	39.10	44.50	39.91±2.25	37.50	43.10	0.03 ^a
VO ₂ max (ml/kg/minutes)	48.93±3.58	44.65	57.46	45.78±4.84	37.10	54.10	0.10 ^a
Hydration status (score)	3.64±1.8	1	6	3.18±2.36	1	7	0.46 ^b
Hemoglobin level (g/dl)	15.44±0.99	13.8	17.3	14.82±0.85	13.4	16.4	0.13 ^a
Physical Activity (kkal/hour)	1.54±0.25	1.24	1.88	1.53±0.25	1.13	1.88	0.85 ^a
Sleep duration (hour)	8.61±1.17	7	10	8.12±1.27	7	11	0.26 ^b

^aIndependent t test, ^bMann-Whitney

TABLE 2. Consumption Level of Nutrient Intake

Variable	Low GL (n=11)			High GL (n=11)			p
	Mean±SD	Min	Max	Mean±SD	Min	Max	
Energy intake (%)	75.78±23.93	44.92	116.67	75.19±21.78	41.63	116.82	0.95 ^a
Carbohydrate intake (%)	67.27±20.78	36.38	106.79	62.91±16.69	31.43	91.07	0.59 ^a
Fat intake (%)	96.37±33.74	48.69	153.41	98.97±24.37	65.01	132.92	0.86 ^a
Protein intake (%)	73.93±28.55	32.99	133.58	73.85±22.73	40.08	120.41	0.99 ^a

^aIndependent t test.

Consumption levels of energy, carbohydrate, fat, and protein intake showed no significant difference between the two groups ($p > 0.05$) (Table 2). Both of groups have low consumption levels of energy, carbohydrate, a protein intake ($< 80\%$) (Gibson 2005). Even so, the average of carbohydrate intake consumption level was higher in the low BG group than the high BG.

The consumption level of carbohydrate intake for endurance athletes is very important to prevent athletes from muscle fatigue. Carbohydrate-rich diets are recommended for endurance exercise because they are associated with increased muscle glycogen stores, liver glycogen concentrations, and delay onset of fatigue (Peinado et al. 2013). Low consumption levels of carbohydrate intake in both groups led to a lack of muscle and liver glycogen stores. This can reduce the rate of ATP regeneration and Ca^{2+} release in the sarcoplasmic reticulum (RS) during exercise (Ørtenblad et al. 2013). As a result the muscles are unable to maintain an adequate supply of energy for contraction and provide strength so that fatigue occurs (Ørtenblad et al. 2013; Wan et al. 2017).

TABLE 3. Blood Glucose, Lactic Acid, BUN Levels in Low and High BG Groups according to Three Times

Variable	Type of Diet		p
	Low GL	High GL	
Blood Glucose			
Before intervention	95.09±15.93	89.55±8.42	0.32 ^a
Immediately after exercise	97±14.18	93.64±9.55	0.52 ^a
Recovery period	87.55±6.23	87.00±6.96	0.85 ^a
Lactic Acid			
Before intervention	2.10±0.55	2.41±0.37	0.14 ^a
Immediately after exercise	6.64±2.02	7.11±3.24	0.69 ^a
Recovery period	2.14±1.00	2.71±1.21	0.19 ^b
BUN			
Before intervention	10.79±1.41	11.26±2.26	0.56 ^a
Immediately after exercise	11.59±1.54	11.30±1.76	0.47 ^b
Recovery period	11.45±1.75	11.37±1.77	0.79 ^b

^aIndependent t test, ^bMann-Whitney

There was no significant difference in blood glucose levels at all three times between the two groups ($p > 0.05$) (Table 3). This finding is similar to previous studies which showed no difference in blood glucose levels immediately after running 2400 meters between the L-L group (low GI low GL) and L-H (low GI high GL) (Siwi et al. 2017). This possible occurred because in this study the carbohydrate content in the low BG group was too low at only 30% (Table 1). Previous studies have suggested low GI foods that are rich in carbohydrate content (1.5 g/kgBW) can help to maintain muscle glycogen and provide fuel for sprint runs with high intensity (Little et al. 2010). Other studies have shown that consuming low-GI low-GL (L-L) foods with a high carbohydrate content of 66% can reduce carbohydrate oxidation and provide blood glucose during exercise (Chen et al. 2008). Too low carbohydrate content in the low GL group, can lead to increased carbohydrate oxidation and further remove muscle glycogen stores during RAST than the high GL group. On the other hand, carbohydrate content in the high GL group was higher than the low GL, which was 47% with moderate IG (59.86). It is possible that the desired effect tends to occur in the high GL group.

Similar to blood glucose levels, lactic acid and BUN levels at all three times also showed no significant difference between the two groups ($p > 0.05$) (Table 3). This finding differs from previous studies which showed differences in lactic acid levels between the L-L group (low GI low GL) with H-H (high GI high GL) and H-L (high GI high GL) during and after a 10 km run test (Chen et al. 2008). However, the increase in post-exercise lactic acid levels was lower in the low BG group compared to the high BG group (Figure 2).

The RAST test is high intensity exercise (> 85% VO₂max) with short duration about 90-120 seconds. This exercise requires glucose as the main energy-producing substrate until the third minute of exercise (Peinado et al. 2013). This exercise will lead to anaerobic glycolysis process to provide ATP in a fast time which produce lactic acid as a residue. Anaerobic glycolysis uses glucose stores which are mostly derived from muscle glycogen and blood glucose to produce ATP (Susilo & Mardiana 2018). Glycogen in skeletal muscle is very important to provide a fast ATP mechanism in muscle cells (Ørtenblad et al. 2013).

The absence of differences in the levels of lactic acid and BUN between the two groups is possible due to the low level of consumption of carbohydrate intake before intervention in the two groups resulting in a lack of muscle and liver glycogen stores in both groups (Ørtenblad et al. 2013). Lack of glucose from glycogen stores and exogenous intake in the interventions in both groups led to gluconeogenesis. During anaerobic conditions, lactate is the main precursor of gluconeogenesis. Gluconeogenesis from lactate is the main production of glucose in the liver and kidneys (Glenn et al. 2015). Lactate is converted into pyruvate by lactate dehydrogenase (LDH) and then produces glucose-6-phosphate and it becomes glucose (Weinstein et al. 2006; Emhoff et al. 2013). The higher levels of lactic acid reflect the higher gluconeogenesis (Emhoff et al. 2013). The level of consumption of carbohydrate intake is equally low in both groups allowing an increase in gluconeogenesis during RAST at the same level which is marked by increasing levels of lactic acid after RAST almost the same in both groups (Table 3).

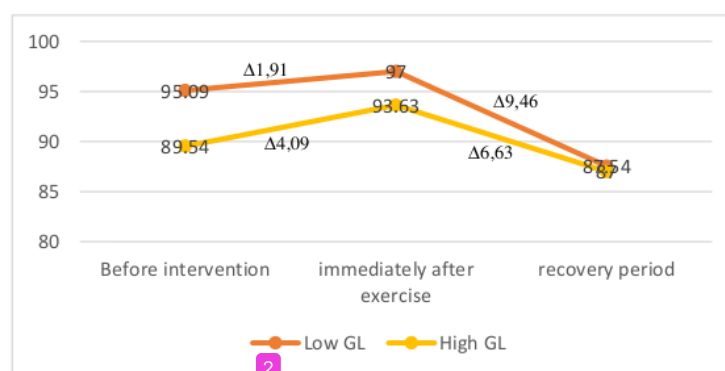


FIGURE 1. Graph of Changes in Blood Glucose Levels in Low GL and High GL Group According to Three Times

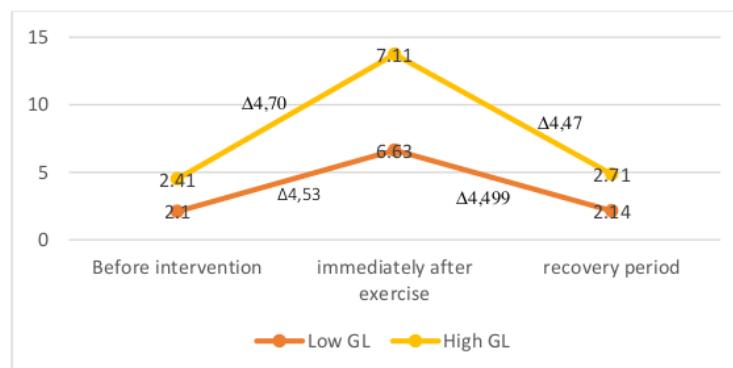


FIGURE 2. Graph of Changes in Lactic Acid Levels in low GL and high GL Group According to Three Times

Although there was no difference between the two groups at all three times, the increase of blood glucose from before the intervention to immediately after exercise was twice lower in the low GL group than the high GL (Figure 1). Lactic acid levels at all three times also showed lower levels in the low GL group (Figure 2). This incident is due to higher protein content (24%) and low glycemic index in the low GL group than the high GL group. The recent study showed that diets high protein with low glycemic index carbohydrates can reduce postprandial hyperglycemia

and lactic acidemia. This diet can increase gluconeogenesis because it provides more major gluconeogenic precursors namely alanine which can be used for endogenous glucose production (Weinstein et al. 2006). Alanine will be converted into pyruvate by alanine aminotransferase then produce glucose-6-phosphate and become glucose (Weinstein et al. 2006; Emhoff et al. 2013).

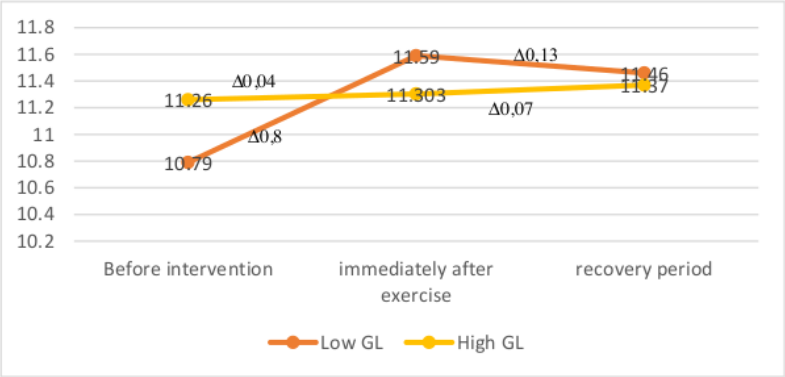


FIGURE 3. Graph of Changes in BUN Levels in low GL and high GL Group According to Three Times

An interesting point is found on the graph of changes in BUN levels in the three times between the two groups. The dynamics of changes in BUN levels was occurred in the low BG group which is an increase BUN levels at immediately after RAST and then a decrease BUN levels during the recovery period. However, this did not occur in the high BG group. BUN levels in the three times are not much different and tend to rise despite the very small increase (Figure 3). This occurs probably because of the high protein content in the diet of low GL group which reaches 24%. Meanwhile, the high BG group only contained 8% protein. The high protein content in the low BG group makes the body increase the oxidation of amino acids that produce urea and ammonia (Probosari 2019). Urea that binds to nitrogen circulates in the blood in the form of blood urea nitrogen (BUN) wherein urea will release excess nitrogen through the kidneys. Urea is used as a marker of protein catabolism. The higher the protein intake, the higher the urea production (Schutz 2011).

The high increase in BUN levels after RAST in the low BG group reflects an increase in the use of protein as an energy substrate during RAST (Palacios et al. 2015). The low carbohydrate content (30%) and high protein content (24%) in the low BG diet results in a lack of glucose availability as an ATP-producing energy substrate resulting in gluconeogenesis with protein substrates. While in the high BG group the carbohydrate content (47%) was still sufficient to meet the energy substrate during the RAST so that the utilization of protein as energy did not occur in the high BG group.

TABLE 4. Fatigue Index and HR Maximal in Low GL and High GL Group After RAST

Type of Diet	Fatigue Index	HR max
Low GL	5,37 \pm 2,06	169,36 \pm 9,71
High GL	6,61 \pm 3,41	173,09 \pm 6,39
<i>p</i>	0,32 ^a	0,30 ^a

^aIndependent t test

Fatigue Index and maximal heart rate after RAST showed no significant difference between the two groups ($p > 0.05$) (Table 4). This is in line with previous studies which showed no difference in travel time completing a 1.46 m run between the RR group (low GI low GL) with TT (high GI high BG) and TR (high GI high GL), although there were differences in metabolic responses between all three groups (Chen et al. 2008). However, the fatigue index and maximal heart rate were lower in the low GL group compared to the high GL group. The difference in mean percent of muscle mass between the low GL and high GL groups ($p < 0.05$) could be the cause of this occurs. Percent of muscle mass in the low GL group was higher than the high GL group.

The amount of muscle mass affects the total amount of creatine in the body (Brosnan et al. 2011). Creatine (Cr) is a type of amino acid that is stored in the muscles as an energy source (Susilo & Mardiana 2018). The anaerobic energy system at RAST, 72% is very dependent in PCr (phosphocreatine) in skeletal muscle (Kim et al. 2011). PCr is broken down into inorganic phosphate (phosphate inorganic/PI) and creatine by creatine-phosphokinase. PI binds to adenosine diphosphate (ADP) molecules to rebuild adenosine triphosphate (ATP) (Susilo & Mardiana 2018). The phosphagen system and creatine phosphate are needed in sprints such as RAST to produce instant energy (Surwase SP, Deore, Deepmala N, Pallod KG 2015). The low GL group had a higher muscle mass percentage (41.92%) than the high GL group (39.91%). This is beneficial for the low GL group because they have higher creatine phosphate deposits than the high GL group. As a result the low GL group can form higher instant energy and have a lower fatigue index than the high BG group.

Although the mean of muscle mass percent between the two groups showed significant differences, the results of multivariate tests showed that the percent of muscle mass when compared with a glycemic load diet did not have an influence on lactic acid levels and BUN ($p > 0.05$) (Table 5).

TABLE 4. Effect of Glycemic Load Diets on Muscle Fatigue After Being Controlled by Muscle Mass Percentages

Variable	Muscle Fatigue	
	Lactic Acid (p)	BUN (p)
Muscle mass percent	0,825 ^a	0,691 ^a
Glycemic load diet	0,464 ^a	0,827 ^a

^ageneral linear model (GLM) repeated measures

The absence of data on muscle glycogen concentration prior to exercise became a limitation in this study because it could not be determined whether there was no difference in physiological responses between the two intervention groups due to pre-existing basal muscle glycogen content or by dietary interventions during the research. Moreover the absence of a standard glycemic index of a food is still debated in this issue. The glycemic index varies and is greatly influenced by many factors including processing, processing time, portion size, geographical area where food grows, and varieties. This causes the estimated glycemic load obtained from IG x carbohydrates to be uncertain for all meals in all portion sizes (Chen et al. 2008). Therefore, it is necessary to test the glycemic index of mixed foods on each diet before be given to athletes.

The type of exercise influences the appropriate type of diet. The RAST is high intensity exercise ($> 85\%$ VO₂max) with a short duration of 90-120 seconds. This exercise requires glucose as the main energy-producing substrate until the 3rd minute of exercise (Peinado et al. 2013). Therefore, it is very important to present a high-carbohydrate-low-GI diet to provide exogenous carbohydrates to maintain blood glucose levels during the RAST. A low GI low GL diet with a composition of 66% carbohydrate, 24% fat, and 15% protein can be a good choice of diet before high intensity short duration exercise. This diet is believed to have a good metabolic response to maintain blood glucose stability and prevents the buildup of lactic acid (Chen et al. 2008). Fruits and vegetables high in fiber, whole-grain cereals, and legumes such as kidney beans, black beans, and peas are a combination of foods that can meet the above diet (Beavers & Leutholtz 2008).

CONCLUSION

Administering a low GL diet 2 hours before RAST compared with a high GL diet did not significantly correlate with muscle fatigue signed by no difference in levels of lactic acid, BUN, and fatigue index between the two groups. However increased blood glucose and lactic acid levels post RAST is smaller in low GL group than high GL group. The right type of diet for high intensity short duration exercises such as RAST is a low GI low GL diet with a 66% carbohydrate composition, 24% fat, and 16% protein.

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