

Influence of Glycemic Index-Based Menu on Endurance Performance of Athletes

Wilda Welis¹, Rimbawan², Ahmad Sulaeman² & Hadi Riyadi²

¹ Faculty of Sports Science, Universitas Negeri Padang, Indonesia

² Departement of Gizi Masyarakat, FEMA, Institut Pertanian Bogor, Bogor, Indonesia

Correspondence: Wilda Welis, Faculty of Sports Science, Universitas Negeri Padang, Jl. Prof. Dr. Hamka – Air Tawar, Padang, Sumatera Barat, Indonesia. E-mail: wildawelis@yahoo.co.id.

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Abstract

Carbohydrate plays an important role in physical activity including in sports. However, consuming high carbohydrates before exercises can cause metabolic effects, *i.e.* unfavorable hyperglycemia and hyperinsulinemia in endurance performance before training. This research is aimed at knowing the influence of meal consumption with different glycemic indexes (GI) on the endurance performance of athletes involving in 5-km run. This research uses controlled random experimental design. The subjects taking part in this research are 15 athletes, consisting of 8 persons in low-GI group and 7 persons in high-GI group. After overnight fasting, the subjects consume the intervening meals in accordance with their groups (low GI or high GI) three hours before 5-km run. The intervening meals contain 1000 calories with glycemic indexes of 37 and 85. The average age of the subjects is 19.0 ± 0.8 years, while the average body weight, body height, and body fat percentage is 56.2 ± 8.9 kg, 163.8 ± 6.8 cm and $17.78 \pm 4.50\%$, respectively. The average hemoglobin, hematocrite, and $VO_{2\max}$ of the subjects is 16.24 ± 1.54 mg/dl, $43.61 \pm 2.81\%$ and 44.99 ± 6.00 ml/kg BB/minutes, respectively. The research findings show that, before and after interventions, the average finish times in 5-km running in the subjects with low-GI group are 23.85 ± 1.64 minutes and 23.91 ± 1.46 minutes faster than those with high-GI group (27.51 ± 2.21 and 26.95 ± 3.11 minutes). This study concludes that there is an influence of meal consumption with different GIs to performance of endurance in 5-km run among college athletes ($p < 0.05$).

Keywords: glycemic index, endurance performance, blood glucose, insulin serum

1. Introduction

Carbohydrate is a main energy-providing nutrient in various physical activities including sports because it can be used immediately to function muscle movement, brain, liver, and red blood cells. The use of carbohydrate increases with increasing sport intensity. The decrease of carbohydrate storage closely relates to an emerging muscle fatigue because of the lowering pyruvate level that triggers the occurrence of ATP-producing Krebs cycle (Powers & Hawley, 1997). The problem faced by an athlete is how to maintain the carbohydrate supply in muscles and to slow down the reduction of muscle glycogen reserve that impairs an emerging fatigue. Thus far, athletes are usually suggested to consume high-carbohydrate meal before participating in a game or training. However, the reality shows that an athlete's endurance to complete the game is yet to be optimal. A rich-carbohydrate meal is suggested for an athlete who does sport activities with physical endurance (Sukmaniah & Prastowo, 1992). However, the high-carbohydrate consumption before training can raise metabolic effects, *i.e.* unfavorable hyperglycemia and hyperinsulinemia in performance before training (Jeukendrup & Gleeson, 2004). The increase of plasma insulin will depress the fat metabolism and increase the carbohydrate oxidation that causes a decrease of plasma glucose concentration for subsequent training. A strategy is needed to minimize the effect of high-carbohydrate consumption in attaining an optimal endurance because heavy sport training can also increase the oxidative stress level. Jenkins *et al.* (1981) published a concept that is corresponding to the carbohydrate known as glycemic index (GI). According to this concept, the carbohydrates contained in meals that are quickly broken down during digestion have a high glycemic index, and the blood glucose response to the meals is quick and high; reversely, the carbohydrates that are broken down gradually have a low glycemic index, releasing glucose slowly into bloods (Rimbawa & Siagian, 2004).

An investigation on glycemic index in trained cyclists, conducted by Thomas *et al.* (1994), found that the

athletes with low-GI consumption have 20-minute longer endurance than those with high-GI consumption. Similarly, Wu and Williams' investigation (2006) indicates that the time taken for completing training is shorter within those consuming low-GI meals than those with high-GI meal, while the rates of fatty oxidation are higher within those with low-GI meal than with high-GI meal. The finding of investigation from Moore *et al.* (2009) also shows that there is a significant increase in performance time after consuming low-GI food rather than that of high-GI food. In addition, the blood glucose concentration at fatigue point is significantly higher after consuming low-GI meal than high-GI meal. This investigation also indicates that there is a significant increase in performance time after consuming low-GI meal in relation to the increase of glucose availability in muscle activity and there is an additional contribution to carbohydrate oxidation and a likelihood of preserving the muscle and liver glycogen reserves.

However, an investigation of Mitchell *et al.* (1997) shows that the consumption of carbohydrate does not influence the endurance during training. Stannard *et al.* (2000) found no significant difference in low-GI and high-GI consumption effects to time of fatigue. Another research conducted by Chen *et al.* (2008) shows no significant difference in the time to complete 50-km running between high-GI and low-GI treatments. From these controversies in the investigation findings of GIs related to endurance, a research is necessary to strengthen the existing findings.

The research aims to study the influences of consuming meals with different GIs on the performance endurance of athletes in 5-km run. The specific objectives were:

- 1) To know the profiles of VO_{2max} , hemoglobin, hemotocrite, and body mass index (BMI)
- 2) To analyze the effects of meals with different GIs on serum insulin and blood glucose levels.
- 3) To test the influence of consuming meals with different GIs on the performance endurance in 5-km run.

2. Methodology

The design of this research is a controlled random experiment that studies the GI effects on the endurance performance of running among college athletes. The subjects of research were male students of 19 – 25 years old. The students are active in sport trainings. Some inclusion criteria are having followed trainings in various sports routinely for at least 6 months, having agreed to take part in this research until its completion by signing an informed consent, is healthy for the last month, not smoking and not drinking alcohol. The number of subjects taking part in this research is 15 persons, who are randomized into two groups of treatments – high-GI group and low-GI group.

The data taken for this research are the subjects' characteristics. These are age, body weight, body height, BMI, and body-fat percentage; venous blood samples for examining the levels of serum insulin, blood glucose and blood lactates, hemoglobin, hematocrite and finish times in 5-km run. The intervening meals with high GI (GI=85) and low GI (GI=37) containing 1000 calories consisting of 70% carbohydrates, 15% proteins and 15% fats for one meal and the meals were provided three times a day during two weeks. The mixed GIs meals are calculated from the table by Foster-Powell *et al.* (2002) as well as from *Warta Penelitian and Pengembangan Pertanian* (2009).

At the initial and final interventions, the samplings of bloods and endurance performances in 5-km run are made three hours following consumption of the meals. The examination of blood glucose concentrations is measured by using a glucometer. The levels of serum insulin are determined by the ELISA method using the commercial kit. The levels of hematocrite are examined with spectrophotometer and the levels of hemoglobin with cyanmethemoglobin. The performances of 5-km running are taken on a treadmill.

The research findings are shown in the form of mean and standard deviation ($x \pm sd$). The influences of meal consumption with different GIs on endurance performance in 5-km run are tested with *t*-tests. To know the influences of meal consumption with different glycemic indexes on blood glucose and serum insulin levels, the ANOVA test is used. The reliability level used for the whole analysis is 95%.

3. Results and Discussion

Body Mass Index (BMI) calculated from body weight and height has played a role in athletes' performances. The results of measurement show that 67% subjects were in the under-nutrient and fat categories. The average BMI in this research is $20.91 \pm 2.81 \text{ kg/m}^2$ and is in the good/normal categories. From the body fat percentage, the subjects were average with $17.7 \pm 4.50\%$ in body fats. This indicates that the subject body fat percentage is in the intermediate category. The body fat percentage is in intermediate category when the value is between 15 and 17 percent for men and 20 and 24 percent for women (Depdiknas, 2000).

The average hemoglobin level within the subjects is 16.24 ± 1.54 g/dl and this value is in the normal category. According to Mougios (2006), the concentrations of normal blood hemoglobin for men of 18 to 44 years old are between 13.2 and 17.3 g/dl. The uptake of lowest maximal oxygen (VO_{2max}) in the subjects with low-GI group is 28.8 ml/kg BB/minutes and with high-GI group 38.5 ml/kg BB/minutes; meanwhile, the highest VO_{2max} in the subjects with low-GI group and high-GI group is 54.38 ml BB/minutes. The tests of differences indicate that there is no significant difference for the subject characteristics ($p>0.05$) in age, body weight, body height, BMI, body fat percentage, hemoglobin, hematocrit and maximal oxygen uptake (VO_{2max}) for both intervened groups. The mean data of subject characteristics is shown in the Table 1.

Table 1. The characteristics of the subjects

Description	High GI (n=7)	Low GI (n=8)	Average (n=15)
Age (years)	19.14 \pm 0.69	18.88 \pm 0.83	19.00 \pm 0.76
Body weight (kg)	58.64 \pm 12.16	54.00 \pm 4.69	56.17 \pm 8.95
Body height (cm)	161.94 \pm 6.49	165.35 \pm 7.13	163.76 \pm 6.82
VO_{2max} (ml/kg BB/min.)	43.78 \pm 6.13	46.04 \pm 6.09	44.99 \pm 6.00
Body fat percentage	19.16 \pm 5.59	16.57 \pm 3.18	17.78 \pm 4.50
Hemoglobin (%)	16.55 \pm 1.33	15.96 \pm 1.75	16.24 \pm 1.54
Hematocrite (%)	43.78 \pm 1.66	43.43 \pm 3.78	43.61 \pm 2.81
BMI (kg/m ²)	21.19 \pm 2.35	19.76 \pm 1.47	20.91 \pm 2.81

In the first day of intervention, the average level of postprandial blood glucose within low-GI group subjects is 98.75 ± 12.08 mg/dl. The average value of postprandial glucose is lower within low-GI group subjects than high-GI group subjects with the average value of 106.29 ± 17.31 mg/dl. However, the average blood glucose after 5-km run in the subjects with low-GI group is in fact higher (110.63 ± 15.97 mg/dl) than in those with high-GI group (102.29 ± 16.23 mg/dl). From the average glucose level two hours after meal consumption (postprandial/PP) with glucose level when fasting, the increase of glucose level in high-GI group is larger than low-GI group. However, from the difference between postprandial (PP) glucose level and running in high-GI group, there is a reduction of blood glucose level after 5-km run. However, statistically there is no average difference of postprandial blood glucose levels within both intervention groups ($p>0.05$). The average blood glucose in the two subject groups can be viewed in Figure 1.

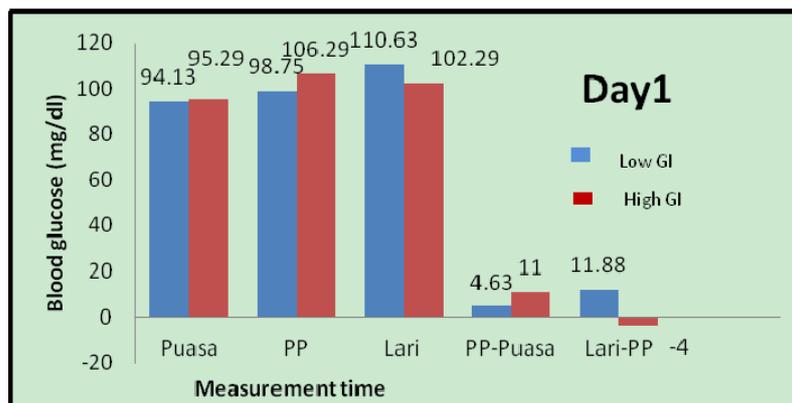


Figure 1. The average blood glucose levels in subjects on day 1

On the 15th day of intervention, the average postprandial blood glucose level is actually higher in the subjects with low-GI group than those with high-GI group. From the difference between PP blood glucose level and glucose level when fasting, the high-GI group is relatively higher than the low-GI group. Similarly, the average difference between glucose level after 5-km run and fasting is shown to be higher in high-GI group than low-GI group. The results of statistical tests suggest that there is no difference of average blood glucose level between the two treatments ($p>0.05$). The average blood glucose level in both treatment groups on day 15 can be viewed

in Figure 2.

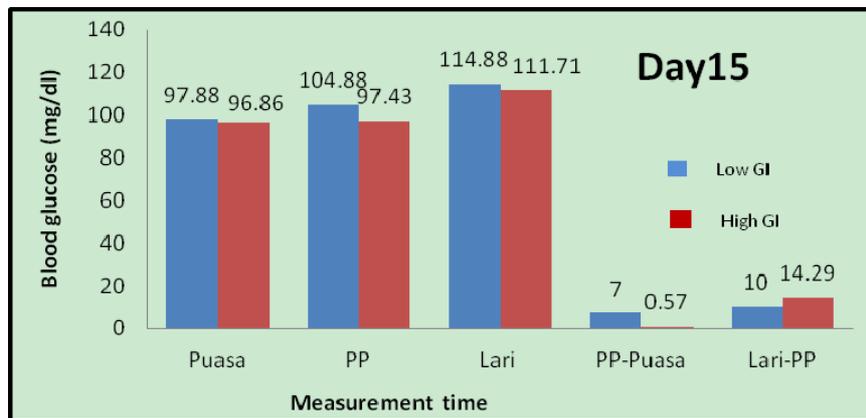


Figure 2. The average blood glucose levels of subjects on day 15

The consumption of high-GI meal is seemingly able to increase the reserve of hepatic and muscle glycogens that is higher than low-GI meal. During training, this glycogen reserve will be broken down by the body as a source of energy. This is in line with the investigation results from Wee *et al.* (2005), which suggests that a high-GI meal consumed before doing sport training/practices provide a greater contribution to muscle glycogen reserve than that of low-GI meal. This suggestion is confirmed by the finding of Burke *et al.* (1993), explaining that the increase of muscle glycogen after 24 hours in recovery from sport practices that exhaust oxygen is higher after consuming high-GI meal than low-GI meal.

In the subjects consuming low-GI meal, the glucose will be released more gradually than those with high-GI meal. The number of blood glucose will be relatively stable in the subjects consuming low-GI meal rather than those consuming high-GI meals. In high-GI meal, the blood glucose level will rise drastically and slow down quickly to basal condition. The low-GI meal is digested slowly so that the storage process is also decreasing. This will be a benefit for an athlete since the glucose will be available until the last sport activities. The high content of muscle glycogens at the time before practices will increase the carbohydrate oxidation (Arkininstall *et al.*, 2004).

The research of Thomas *et al.* (1994) suggests that the plasma glucose level after training relates to GI in the food provided before training. In consuming a high-GI meal before practicing sport, the concentration of blood glucose will rise and lower sharply and attain a higher level at peak times than in consuming low-GI meal with similar number of carbohydrates (Mondazzi *et al.*, 2009). This finding is confirmed by Burke *et al.* (1998) and Cocate *et al.* (2011) suggesting that the rate of glucose oxidation is higher after consuming high-GI meal.

The decrease of blood glucose level occurs after 5-km run within high-IG group; this is presumably caused by the insulin level after meal consumption (before training) is still high enough in high-GI group, bringing the glucoses into liver and muscle to be stored as glycogens and reducing the glucose production in liver (Marmy-Cornus *et al.*, 1996). As Coyle (1991) said, the influence of insulin on peripheral tissue is seemingly longer although the insulin level has reduced to the fasting level. This influence of stable increasing insulin level is likely to enable blood glucose uptake by muscles remaining to be elevated in high-GI group rather than in low-GI group (Wee *et al.*, 1999).

Insulin is an important hormone, which regulates the use of energy by body tissues. Insulin provides anabolic effects in body metabolism such as the forming of glycogens, triacylglycerol and proteins. On day 1 during the intervention, the average level of blood insulin within the subjects in low-GI group is 7.98 ± 4.85 μ IU/mL, while for those in high-GI group it is 10.21 ± 8.11 μ IU/mL. After meal consumption, the average level of serum insulin in the high-GI group is higher than in the low-GI group; it happens also with the average level of serum insulin after 5-km run on treadmill. After running, the insulin level of both treatment groups experience a reduction, and the highest average difference of insulin reduction occur in the high-GI group. The results of statistical tests suggest that on day 1, there is a significant difference in the average level of serum insulin after meal consumption in the two treatments ($p < 0.05$). The average levels of serum insulin in the first-day measurement in both treatment groups is shown in Figure 3.

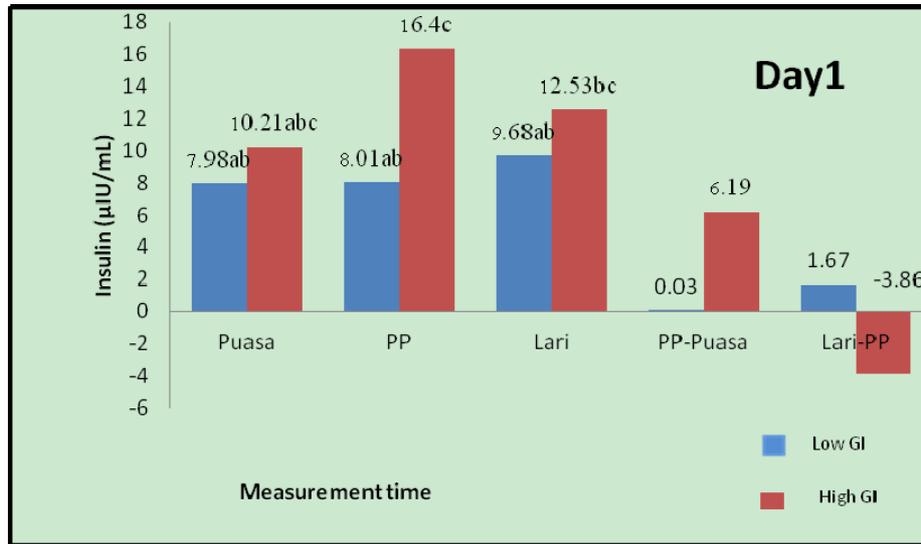


Figure 3. The average levels of serum insulin on day 1

This finding is similar with the research of Stevenson *et al.* (2005) in which he has consumed the mixtures of high GI and low GI meals at breakfast and lunch before running on treadmill and found that postprandial insulin concentrations after 1 hour and 2 hours are significantly higher in the high GI than in the low GI. In the initial training, the value of insulin concentration is similar to the fasting value in low GI, but in high GI it remains 150% higher than the value of insulin concentration when fasting. This is also suggested by research conducted by Wong *et al.* (2008) in which he provided the mixtures of high GI and low GI meals containing 65% carbohydrates, 15% proteins, and 20% fats of the total calories. He found that the concentration of serum insulin during postprandial period is higher in high-GI meal than in low-GI meal. The finding of Stevenson (2006) in the female subjects who were given high- and low-GI breakfasts also suggests that the concentration of serum insulin is significantly higher in high-GI treatment than low-GI treatment, and the concentration of insulin is reduced following the postprandial period of both treatments but remains higher in high-GI than low-GI treatment ($p < 0.05$).

On the 15th day of intervention, the average level of serum insulin two hours after meal (postprandial) and after 5-km run within high-GI group is relatively higher than low-GI group. The pattern of increasing serum insulin level in high-GI group is in line with the increasing blood glucose level in high-GI group both in PP and after 5-km run. The average level of serum insulin on the 15th day measurement within the two treatment groups is shown in Figure 4.

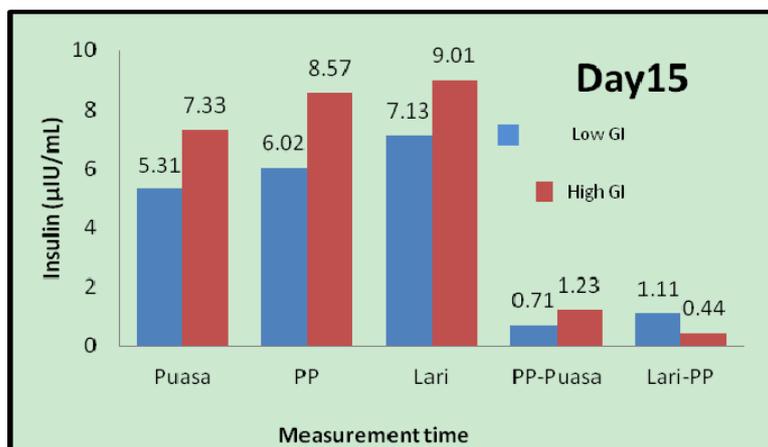


Figure 4. The average levels of serum insulin on day 15

On the 15th day, seemingly the subject bodies underwent an adaption condition so that the difference of insulin

levels two hours after meal consumption is not seen; however, a tendency of serum insulin level within high-GI group is still larger than low-GI group. The increase in insulin level after meal consumption and after 5-km run on the day 15 is caused by the increases in glucose level in high-GI group. Apparently digestion and absorption processes of food still exist, therefore the glucose is still increasing (Wee *et al.*, 1999). The main factors that contribute to regulating the blood glucose levels are the blood glucose concentration itself and the hormones particularly insulin and glucagon (Marks *et al.*, 2000).

Endurance can be connoted with a body ability to resolve fatigue or body capacity to receive burdens as long as possible both in static and dynamic situations without reducing work quality. In this research the endurance performance is defined as the ability of subject to complete 5-km run within a certain time. On the first day of intervention, the research findings show that the average finishing time for 5-km run in low-GI group is 23.8 ± 1.6 minutes lower than in high-GI group (27.5 ± 2.2 minutes). On the 15th day of intervention, the finishing time of 5-km run in low-GI group remains lower (23.9 ± 1.5 minutes) than in high-GI group (26.9 ± 3.1 minutes). There is a significant difference in the finishing time of 5-km run between the two treatment groups ($p < 0.05$). The average performance of 5-km run endurance can be seen in Table 2.

Table 2. The endurance performance in 5-km run

Variable	Time	Low IG (n=6)	High IG (n=6)	p value
Time (minutes)	Day 1	$23.8 + 1.6$	$27.5 + 2.2$	0.008
	Day 15	$23.9 + 1.5$	$26.9 + 3.1$	0.05
	p value	0.915	0.573	

There is an effect of meal consumption with different GI on the time necessary for subjects to finish the 5-km run. The performance or the finishing time in 5-km run in low-GI group is better than that of high-GI group both before and after interventions. The shorter time taken for finishing the 5-km run in high-GI group when compared with high-GI subjects is presumably because the subjects consuming low-GI meal have relatively more stable glucose availability as an energy source than those consuming high-GI meal. The result of this research is in line with the research conducted by Wong *et al.* (2008) which suggests that the subjects with low-GI meal show faster finishing times when compared with those with high-GI meal (low GI = 98.7 minutes and high GI = 101.5 minutes). The same result of investigation is also obtained from Wu and Williams (2006), which suggest that the endurance capacity of subjects taking low-GI meal three hours before running on treadmill is larger than those with high-GI meal. Moore *et al.* (2009) also concludes that the performance of cyclists significantly increased in low-GI treatment (92.5 ± 5.2 minutes) rather than high-GI treatment (95.6 ± 6.0 minutes).

The faster time in reaching the finish line in low-GI intervention can be explained by the probable large number of carbohydrates that have not been oxidized still remains in the small intestine on initial sport activities and are subsequently released into blood gradually (Burke *et al.*, 1998; Thorne *et al.*, 1983). The meal with high GI experienced faster digestion and absorption, and glucose transport into the circulation system, causing the larger blood glucose frequency than low-GI meal. In high-GI meal, the blood glucose will be stored optimally as muscle glycogens that are reduced as they are used in doing sports. This is similar to the finding of Wong *et al.* (2008), which suggests that the blood glucose concentration remains high during sport activity after consuming low-GI meal. Moore *et al.* (2000) in his research also describes that the blood glucose level at fatigue point after bicycling is higher in low-GI treatment (5.2 ± 0.6 mmol/L) than high-GI treatment (4.7 ± 0.7 mmol/L). According to Marmy-Conus *et al.* (1996), this response could happen because, after consuming high-GI meal, the serum insulin concentration during postprandial is higher that it plays a role in reducing the hepatic glucose production and increasing the glucose transport into muscles. The influence of insulin concentration on peripheral tissue sustains for longer time, although the concentration will return to the fasting value (Coyle, 1991; Montain *et al.*, 1991). The influence of sustainable hyperinsulinemia causes the increase of glucose uptake during the high-GI consumption become larger than that of during the low-GI consumption (Wee *et al.*, 1999).

In high-GI treatment, the availability of hepatic glycogen reserve has been adequate, and possibly the sport practice causes the increasing hepatic glucose output that is simultaneous to the increasing glucose uptake by muscles during the sport training. When the sport practice continues, the hepatic glycogen storage will be inadequate to meet the increasing glucose uptake by muscle, causing the drastic reduced glucose concentration until the last training. This can explain why the blood glucose concentration is more stable in low IG treatment

and decreases to the fasting value in the last training in high-GI treatment (Wong *et al.*, 2008). The reduction of carbohydrate reserve is one of the primary causes for an exacerbation of performance and an increase of fatigue during the long-term sport in sub-maximal running (Wong & Williams, 2000). According to Costill, the muscle glycogens depend on training intensity, physical condition, training type, environmental temperature, and meal before training (Costill, 1988). The reduction of carbohydrates causes the inability of muscles to produce ATP again as the rate of ATP decreases. The inadequacy of carbohydrates leads to the reducing pyruvate in muscles as substrates in forming acetyl CoA and in trycarboxylate acid reaction.

4. Conclusion and Suggestion

The endurance performance of 5-km run is better in low-GI group than in high-GI group; this is because there is an influence of meal consumption with different GIs on the college athletes ($p < 0.05$). On the first day of intervention, there is a significant difference in the average level of postprandial insulin between the two treatments ($p < 0.05$); however, on the 15th day of intervention there is no difference in the average level of insulin between the two treatments but there is a higher tendency of average insulin level in high-GI than low-GI treatments. There is no significant difference in the average blood glucose level between treatments, but there is a higher tendency of blood glucose level after 5-km running in low-GI treatment both on the first and 15th days of interventions.

Based on the results of the research it can be concluded that the consumption of low-GI meal before sport activity can better improve the performance in 5-km run. The relevant stakeholders should hold an awareness campaigns or programs about proper meal intake to reach an optimal performance for athletes, especially related to glycemic index of the meals.

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