KEMAS 16 (3) (2021) 394-401

Jurnal Kesehatan Masyarakat

http://journal.unnes.ac.id/nju/index.php/kemas

Low and High Glycemic Load Diet on Immune Responses of Adolescent Football Athletes

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Article Info

Article History:
Submitted Oktober 2019
Accepted June 2020
Published November 2020

Keywords:
glycemic load diet, immune responses, leukocytes, leukocyte differential count

DOI
https://doi.org/10.15294/kemas.v16i2.21357

Abstract

High-intensity physical exercise causes physical stress that will suppress immune system in athlete's body. Decreased immune system function can cause physiological and pathological changes such as fatigue, reduce athlete performance, and increase risk of infection. Regulation diets of glycemic index (GI) and glycemic load (GL) are known to help control blood glucose during exercise so the immune system can be maintained.The purpose of this study was to determine differences effects of low and high glycemic load diets on immune responses in adolescent football athletes. This study was a quasi experimental with multiple time series design, conducted on 22 adolescent football athletes aged 15-17 years old. The subjects were divided into two groups, low GL diet group was given carbohydrate-source foods with GL 9.15, high GL diet group was given foods with GL 27.29. Diet was given once in the morning and 2 hours later subjects doing RAST (Running-based Anaerobic Sprint Test) to trigger physical stress. Immune response was measure using total leukocytes and leukocytes differential count. There were no significant differences in blood glucose levels, leukocyte counts, and leukocytes differential count between low GL and high GL groups ($p>0.05$). Low GL diet causes an increase in blood glucose and total leukocytes smaller than high GL diet.

Introduction

Football is a high-intensity endurance sport that lasts for 90 minutes (Kirkendall, 2011). High intensity exercise can cause physical stress and lead to immunodepression in athlete's body (Gleeson, 2007; Gunzer, Konrad and Pail, 2012). Decreased immune function result in increase risk of infection in athletes so that it can interfere the recovery process and reduce performance during the next competition or training (Gunzer, Konrad and Pail, 2012). Previous studies have shown that some aspects of immune function do not return to normal until several hours after exercise so that it has implications for the susceptibility of upper respiratory tract infections (Kakanis et al., 2010). Other studies conducted on soccer athletes report that salivary immunoglobulin A (s-IgA) concentrations are significantly lower after high intensity exercise rather than low intensity exercise. s-IgA is a marker to predict the risk of infection in endurance athletes, decrease s-IgA concentration can increase the risk of infection in athletes (Owen et al., 2016).

Immune responses that occur due to physical exercise are increase of leukocytes, neutrophils, monocytes, lymphocytes and natural killer cells (Maughan and Gleeson, 2010). Previous study have reported that leukocytes, neutrophils, lymphocytes, eosinophils, monocytes, basophils increased after high intensity exercise (75% Maximum heart rate) (Abdossaleh et al., 2014). Impaired immune function because of pphysical exercise

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pISSN 1858-1196
eISSN 2355-3596

caused by an increase levels of stress hormones such as cortisol and catecholamine (Gleeson, 2007; Maughan and Gleeson, 2010). Increased cortisol not only occurs during exercise with high intensity but also depends on blood glucose availability. Low blood glucose will increase blood cortisol levels (Nieman, 2008).

The strategy of providing good nutrition to athletes can maintain immune system condition (Gunzer, Konrad and Pail, 2012). One of the nutrients that is important to maintain the immune system is carbohydrate (Karacabey and Ozdemir, 2012). Providing of appropriate carbohydrates will maintain the availability of blood glucose during training or competition (Burke et al., 2011). Sufficient carbohydrate availability and stable blood glucose levels can reduce stress hormone responses, provide glucose as an energy substrate for immune cells and maintain immune system (Gleeson, 2006). Adequate intake of carbohydrates is a major factor to maintain athlete performance (Gunzer, Konrad and Pail, 2012).

In recent years athletes have been introduced to provide carbohydrates by regulating the glycemic index. Glycemic index (GI) is a number that shows the increase potential of blood glucose from carbohydrate contents in a food (Beavers, Kristen M., Leutholtz, 2008). Previous studies have shown that consumption of high carbohydrates foods with low GI can maintain blood glucose stability during exercise (Wong et al., 2008). The stability of blood glucose can reduce levels of stress hormones such as cortisol, so that the immune system is maintained (Nieman, 2008). The glycemic index only indicates the type of carbohydrate, without considering the total amount of carbohydrate contents in a food, which can also have an impact on blood glucose (Beavers, Kristen M., Leutholtz, 2008). The GI is perfected by the glycemic load (GL). GL is the amount of carbohydrate and IG in a food, which will affect the blood glucose level after consuming it (Augustin et al., 2015). GL can more accurately describe the effect of food on blood glucose levels (Beavers, Kristen M., Leutholtz, 2008). A study conducted on adolescent soccer athletes showed that consumption low GI and low GL diet 2 hours before exercise will stimulate smaller metabolic changes, it causes blood glucose are more stable during exercise (Siwi, Dieny and Fitranti, 2017).

Previous studies aimed to examine the effect of GI and GL diets on immune responses in running athletes. As a result, consumption low GI and a low GL diet of 2 hours before exercise causes smaller changes in leukocytes, neutrophils, and lymphocytes than consumption high GI and low GL diet (Chen et al., 2008). Other studies stated that there is no effect of consumption carbohydrate-containing foods with diffetence of GI and GL 2 hours before exercise on immune function (Li, 2015). The immune response is influenced not only by nutrient intake, but also by age, sex, stress conditions (physical and psychological stress), sleep disturbance, duration, frequency, and intensity of exercise (Gleeson, 2006; Walsh, 2018). The purpose of this study is to analyze the difference effect of high glycemic load diet and low glycemic load diet of 2 hours before exercise on leukocytes and leukocytes differential count (neutrophils, lymphocytes, eosinophils, monocytes).

Method

This research was conducted at the Terang Bangsa Semarang Football School. This research was a quasi experimental, multiple time series design with 2 treatment groups. Each group consisted of 11 people chosen through simple random sampling. The inclusion criteria of subjects was men aged 15-18 years, join in football club for at least 1 year, minimum follow 90% attendance of physical training in the last 12 weeks, not consume carbohydrate-based supplements or sports drinks, coffee, and tea 24 hours before the study, not smoking and consume alcohol, not being sick, injured, or in the care of a doctor, not do high intensity physical exercise 24 hours before the intervention.

The subjects in this study were divided into two groups: group 1 was given a low GL diet and group 2 was given a high GL diet. 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). Diet was given once at 2 hours before training. Two hours after eating GL diet, subjects did

RAST (Running-based Anaerobic Sprint Test) exercise to trigger physical stress in athlete's body. RAST method is performed by subjects being asked to six times sprints run on a 35 meter straight track with maximum speed with a 10-second pause between each repitition.

Table 1. Nutritional Composition of Preexercise Meals

	High GL (Medium GI – High GL/ M-H)	Low GL (Low GI – Low GL/ L-L)
Energy	391,53 kkal	400,18 kkal
Carbohydrate	45,57 g (47%)	28,77 g (30%)
Fat	19,47 g (45%)	20,66 g (46%)
Protein	9,09 g (8%)	23,56 g (24%)
Estimated mix GI	59,86	31,79
Estimated mix GL	27,29	9,15
Food contents	Boiled corn (100 g)	Boiled spaghetti (90 g)
	Sweetened condensed milk (40 g)	Srambled egg (50 g)
	Cheddar cheese (20 g)	Corned beef (25 g)
	Margarine (10 g)	Palm oil (10 g)

Subject characteristics data including name, age, and date of birth were taken using a questionnaire. Body Mass Index (BMI) data were measure using the Bioelectric Impedance Analyzer (BIA). Physical activity data was measured using the Physical Activity Level (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. Data on stress conditions (psychological stress) athletes were measured using the The Perceived Stress Scale (PSS) questionnaire. Sleep quality data were measured using the Pittsburgh Sleep Quality Index (PSQI) questionnaire. All this data was taken the day before the study was conducted.

Blood samples were taken to measure blood glucose levels, total leukocytes, and leukocytes differential count. Blood samples were taken 3 times, those are before the intervention, immediately after the RAST, and 1 hour after the RAST. Blood glucose levels are measured using a glucometer from a peripheral blood vessels at the fingertips. Blood samples from veins were taken to measure the total leukocytes and leukocytes differential count, then the blood samples was analyzed in the laboratory. Statistical analysis in this study was using the independent-t-test if the data was normally distributed and Mann-Whitney test if the data was not normally distributed. The statistical analysis was used to examine the difference of blood glucose level, total leukocytes, leukocytes differential count, and other variables before the intervention, immediately after the RAST, and 1 hour after the RAST between two groups.

Table 2. Subject Characteristics and Adequacy Level of Nutrient Intake in Both Groups

Subject Characteristics	Low GL (n=11)			High GL (n=11)			p
	Mean±SD	Min	Max	Mean±SD	Min	Max	
Age (year)	16,00±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]
VO_2max (ml/kg/minutes)	48,93±3,58	44,65	57,46	45,80±4,84	37,10	54,10	0,09[a]
Physical activity (kcal/hour)	1,54±0,25	1,24	1,88	1,53±0,25	1,13	1,88	0,85[a]
Stress condition (score)	6,55±2.02	3	10	7,27±2,05	4	11	0,41[a]
Sleep quality (score)	15,18±3,60	8	19	15,91±4,16	10	22	0,67[a]
Adequacy Level of Nutrient Intake	**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	98,7±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]

Vitamin A intake (%)	301,75±101,17	132	488,87	339,93±70,72	212,7	478,7	0,32[a]
Vitamin B6 intake (%)	79,02±26,89	46,15	138,46	88,11±20,46	61,54	123,08	0,38[a]
Vitamin C intake (%)	22,9±28,79	0,67	89,89	15,31±19,08	0	65,22	0,67[b]
Vitamin E intake (%)	0,36±1,00	0	3,33	0,48±1,61	0	5,33	0,62[b]
Zinc intake (%)	50,16±18,32	27,65	87,06	53,2±9,82	37,65	66,47	0,61[a]
Iron intake (%)	50,42±21,58	29,33	103,33	53,39±9,66	40	70	0,24[b]

[a]Independent-t-test, [b]Mann-Whitney

Adequacy level of nutrient intake including energy, carbohydrate, fat, protein, vitamin A, B6, C, E, zinc and iron intake showed no significant differences between two groups (p>0.05) (Table 2). Energy, carbohydrate, and protein intake of the two groups lower than their needs (<80%). However, mean value of carbohydrate intake level was higher in the low GL group than the high GL group. Mean value of blood glucose levels before the intervention were 95.09 mg/dL in the low GL group and 89.55 mg/dL in the high GL group. There were no significant differences in blood glucose levels before intervention between the two groups (p>0.05) (Table 3). This shows that the condition of two groups before intervention was in the same condition.

Table 3. Blood Glucose Level in Both Groups according to Three Times

Type of Diet	Blood Glucose Level (Mean±SD)		
	Before intervention	Immediately after exercise	1 hour after exercise
Low GL	95,09±15,93	97,00±14,18	87,55±6,23
High GL	89,55±8,42	93,64±9,55	87,00±6,96
p	0,32[a]	0,52[a]	0,85[a]

[a]*Independent-t-test*

This study showed no significant differences in blood glucose levels immediately after RAST exercise test and 1 hour after RAST exercise test (recovery period) between low GL dan high GL groups (p>0.05). Previous study also showed the same results that there was no difference in blood glucose levels immediately after 2400 meters running between the low GI-low GL group and the low GI-high GL group (Siwi, Dieny and Fitranti, 2017). That might happen because carbohydrate content in this study was too low, only 30% in the low GL group (Table 1). Other study have suggested that consuming high carbohydrate diet with low GI can increase muscle glycogen stores and provide fuel for high intensity exercise (Little et al., 2010). Previous study have shown that consuming low GI-low GL meal with a high carbohydrate content (66%) can reduce carbohydrate oxidation and provide the blood glucose during exercise (Chen, Wong and Wong, 2008). Low carbohydrate content in the low GL group may cause earlier remove muscle glycogen stores during RAST exercise and lead to increased carbohydrate oxidation.

There was no difference in blood glucose levels at all three times between the two groups, but an increase of blood glucose levels from before intervention to immediately after exercise was lower in low GL group (Δ = 1.91 mg/dL) than high GL group (Δ = 4.09 mg/dL) (Figure 1). These results was similiar with previous studies which showed the increase of blood glucose levels in the low GI-low GL diet group occurred slowly for 2 hours after eating and during exercise (Chen, Wong and Wong, 2008). Decrease of blood glucose levels after 1 hour exercise (recovery periode) in the low and high GL group because the decrease of muscle glycogen immediately after exercise. Low carbohydrate content in diet of both groups (<50%) causes the use of blood glucose for glycogen re-synthesis and causes blood glucose decrease in both groups during recovery periode. (Figure 1) (Rollo, 2014)

Table 4. Total Leukocytes And Leukocytes Differential Count in Both Groups according to Three Times

Variable	**Mean**±SD		*p*
	Low GL Diet	**High GL Diet**	
Total Leukocytes			
Before intervention	7,37±1,28	7,32±1,94	0,95[a]
Immediately after exercise	10,07±1,01	11,17±3,91	0,67[b]
1 hour after exercise	6,98±1,02	8,12±2,83	0,25[b]
p	0,00[c]	0,00[d]	
Neutrophils			
Before intervention	50,55±5,65	55,09±8,75	0,16[a]
Immediately after exercise	44,73±9,37	49,18±11,33	0,33[a]
1 hour after exercise	55,59±5,79	63,09±8,51	0,03[a]
p	0,00[c]	0,00[c]	
Lymphocytes			
Before intervention	39,9±6,56	33,82±7,48	0,05[b]
Immediately after exercise	46,00±9,12	40,82±10,30	0,23[a]
1 hour after exercise	35,55±5,39	28,00±7.00	0,01[a]
p	0,00[c]	0,01[d]	
Monocytes			
Before intervention	7,45±1,44	8,09±2.47	0,71[b]
Immediately after exercise	7,82±1,17	8,09±1.76	0,81[b]
1 hour after exercise	7,09±1,14	7,64±2.42	0,84[b]
p	0,03[d]	0,27[d]	
Eosinophils			
Before intervention	2,09±1,04	3,00±1.41	0,10[a]
Immediately after exercise	1,45±0,69	1,82±0.87	0,26[b]
1 hour after exercise	1,45±1,04	1,27±0,90	0,78[b]
p	0,00[d]	0,00[d]	

[a]Independent-t-test, [b]Mann-Whitney, [c]Repeated ANOVA, [d]Friedman

Total leukocytes and leukocytes differential count (neutrophils, lymphocytes, monocytes, eosinophils) at all three times between low GL and high GL group showed no significant difference ($p>0.05$), except neutrophils and lymphocytes 1 hour after exercise showed significant difference between two groups ($p<0.05$) (Table 4). These results differ from previous studies which showed that there were significant differences total leukocytes and neutrophils between the low GI-low GL diet group and high GI-low GL diet group (Chen et al., 2008). There was no difference between two groups in this study probably because of differences physical stress exposure from the exercise compared to previous study. Exercises in previous study was constant running at 70% VO2max for 1 hour and then followed by 10 km running (Chen et al., 2008). So, besides the intensity of the exercise, the duration of the exercise also affects changes in the body's immune system (Terra et al., 2012; Palmowski et al., 2019). Impaired immune function after exercise is greater when exercise occurs continuously and prolonged (1.5 hours), with moderate to high intensity (VO2max 55-75%) (Gleeson, 2007). Long duration intensive exercises such as marathon or ultramarathon can suppress immune system function (Palmowski et al., 2019).

Carbohydrate intake of subjects 1 day before intervention were less than normal

requirements in both groups. This may be another reason there is no difference in total leukocytes between two groups. Low carbohydrate intake causes a lack of muscle and liver glycogen stores. Lack of glycogen stores can reduce the rate of ATP regeneration and release of Ca2+ in the sarcoplasmic reticulum during exercise, so the muscles are not able to provide enough energy for muscle contraction during exercise (Ortenblad, Wasterblad and Nielsen, 2013). Adequate carbohydrate intake can increase the availability of blood glucose during exercise and prevent an increase cortisol levels so the function of immune cells is maintained (Ziaolhagh and Naghibi, 2012).

This study showed that an increase of total leukocytes before intervention and immediately after exercise between two groups. That was similiar with previous study, there was an increase of total leukocytes after 10 km running on subjects given GI and GL diets (Chen et al., 2008). Other study also showed an increase of total leukocytes after playing football and running. This happens because high intensity exercise produces high physical stress, causing changes in total leukocytes (Cenikli, 2016).

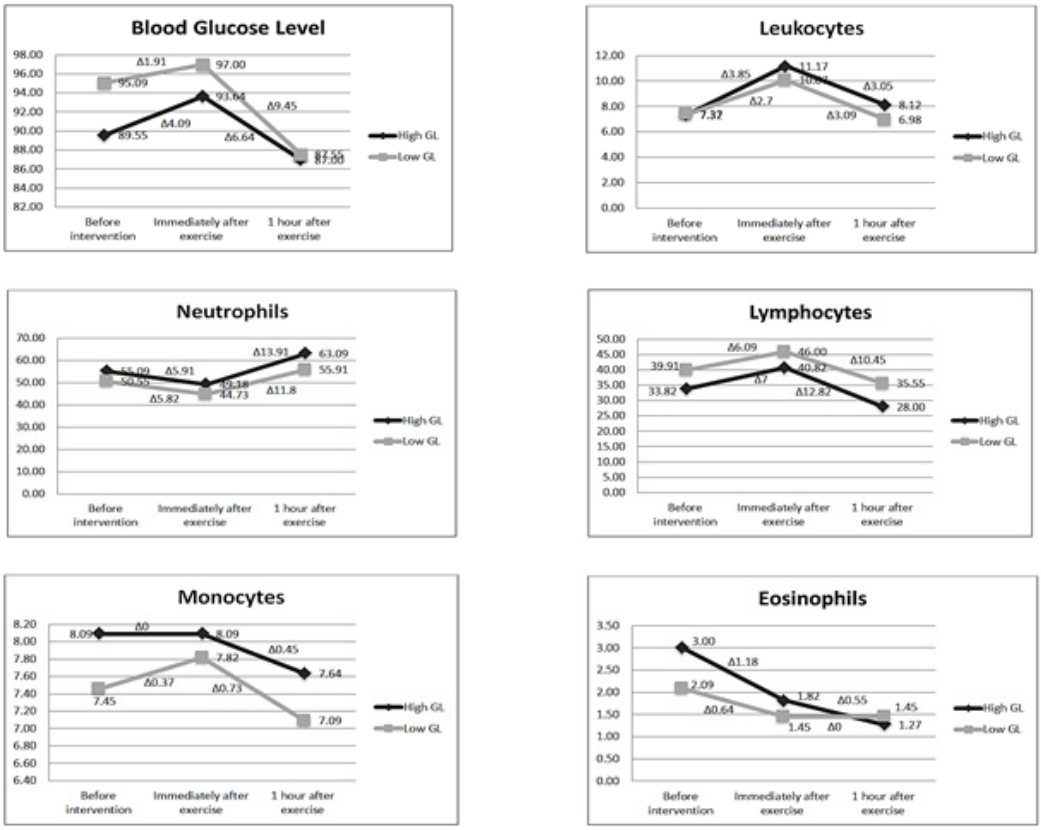

Figure 1. Graph of Change Blood Glucose, Leukocytes, Neuthrophils, Lymphocytes, Monocytes, and Eosinophils Level in Both Groups According to Three Times

Although total leukocytes at three times showed no difference between low GL and high GL groups, the increase of total leukocytes before intervention to immediately after exercise was lower in the low GL group (Δ = 2.7x103 µL) than high GL group (Δ = 3.85x103 µL) (Figure 2). That was probably because the diet in the low GL group contained low GI food. Consumption of foods with low GI before exercise has more potential to maintain the availability of blood glucose during exercise (Wong et al., 2008; Little et al., 2010). Stable blood glucose can prevent the increase in stress hormones and maintain immune system function. (Nieman, 2008; Gleeson, Bishop and Walsh, 2013).

Changes in total leukocytes and leukocytes differential count can occur due to

the short-term (acute) effects of high-intensity exercise. These changes occurred immediately after exercise until 2 hours after exercise (Neves et al., 2015). In this study an increase of leukocytes, lymphocytes, monocytes, and a decrease of neutrophils and eosinophils after exercise between both groups. Previous studies have shown that there was an increase in leukocytes, neutrophils, lymphocytes, and monocytes immediately after 10 km running on subjects who were given a carbohydrate diet with the regulation of GI and GL (Chen et al., 2008; Li, 2015).

The increase in leukocytes (leukocytosis) due to acute exercise is temporary because the amount will return to the resting value 6-24 hours after exercise. Leukocytosis from physical exercise is caused by mobilization or changes in the number of neutrophils and lymphocytes, as well as the small contribution of monocytes. High-intensity exercise that lasts briefly (several minutes) can cause an increase in neutrophils to 2 times more, while endurance training that lasts long causes an increase in neutrophils to 3-4 times more (Gleeson, Bishop and Walsh, 2013).

There are several limitations in this study, such as no data about muscle glycogen stores and blood cortisol levels. Muscle glycogen will affect blood glucose levels during exercise so it will affect the hormone cortisol and cause changes in the immune system. In addition, this study did not directly test the glycemic index of food on blood glucose levels, only through the calculation of various references. Even though there is no standard for the glycemic index of food so the values are different and make the glycemic load of food also different.

Conclusion

There was no difference effect of high and low glycemic load diets of 2 hours before Running-based Anaerobic Sprint Test (RAST) on the immune response of adolescent football athletes characterized by no differences in total leukocytes and leukocyte differential count (neutrophils, lymphocytes, monocytes, and eosinophils). However, increases in blood glucose levels and total leukocytes after RAST were lower in the low GL diet group. High-carbohydrate diets (> 60%) with low GI and low GL can be used to high intensity exercise.

References

Abdossaleh, Z., Fatemeh, A., Frozan, K., & Amin, S.M., 2014. Leukocytes Subsets is Differentially Affected by Exercise Intensity. International Journal of Sport Studies, 4(2), pp.246–253.

Augustin, L.S.A., Kendall, C.W.C., Jenkins, D.J.A., Willett, W.C., Astrup, A., Barclay, A.W., Bjorck, I., Brand-Miller, J.C., Brighenti, F., Buyken, A.E., Ceriello, A., Vecchia, C. La., Livesey, G., Liu, S., Riccardi, G., Rizkalla, S.W., Sievenpiper, J.L., Trichopoulou, A., Wolever, T.M.S., Baer-Sinnott, S., & Poli, A., 2015. Glycemic Index, Glycemic Load and Glycemic Response: An International Scientific Consensus Summit from the International Carbohydrate Quality Consortium (ICQC). Nutrition, Metabolism and Cardiovascular Diseases, 25(9), pp.795–815.

Beavers, K.M., & Leutholtz, B., 2008. Glycemic Load Food Guide Pyramid for Athletic Performance. Strength and Conditioning Journal, 30(3), pp.10–14.

Burke, L.M., Hawley, J.A., Wong, S.H., & Jeukendrup, A.E., 2011. Carbohydrates for Training and Competition. Journal of Sports Sciences, 29. pp.S17–S21.

Cenikli, A., 2016. Comparison of Effects of Running and Playing Exercises on Differential Leucocyte Count in Young Elite Athletes. International Journal of Environmental and Science Education, 11(6), pp.1319–1322.

Chen, Y.J., Wong, S.H., Wong, C.K., Lam, C.W., Huang, Y.J., & Siu, P.M.F., 2008. The Effect of a Pre-exercise Carbohydrate Meal on Immune Responses to an Endurance Performance Run. British Journal of Nutrition, 100(6), pp.1260–1268.

Chen, Y.J., Wong, S.H., & Wong, C.K., 2008. Effect of Preexercise Meals with Different Glycemic Indices and Loads on Metabolic Responses and Endurance Running. International Journal of Sport Nutrition and Exercise Metabolism, 18, pp.281–300.

Gleeson, M., 2006. Immune Function in Sport and Exercise-advances in Sport and Exercise Science Series. Philadelphia: Churchill Livingstone Elsevier.

Gleeson, M., 2007. Immune Function in Sport and Exercise. J Appl Physiol, 103, pp.693–699.

Gleeson, M., Bishop, N., & Walsh, N., 2013. Exercise Immunology. 1st edn. London: Routledge.

Gunzer, W., Konrad, M., & Pail, E., 2012. Exercise-

induced Immunodepression in Endurance Athletes and Nutritional Intervention with Carbohydrate, Protein, and Fat-what is Possible, What is Not?. Nutrients, 4(9), pp.1187–1212.

Kakanis, M.W., Peake, J., Brenu, E.W., Simmonds, M., Gray, B., Hooper, S.L., & Gradisnik, S.M.M., 2010. The Open Window of Susceptibility to Infection After Acute Exercise in Healthy Young Male Elite Athletes. Exercise Immunology Review, 16, pp.119–137.

Karacabey, K., & Ozdemir, N., 2012. The Effect of Nutritional Elements on the Immune System. Journal of Obesity & Weight Loss Therapy, 2(9), pp.1–6.

Kirkendall, D.T., 2011. The Complete Guide to Soccer Fitness and Injury Prevention: A Handbook for Players, Parents and Coaches. The University of North Carolina Press.

Li, D., 2015. The Research on the Effect of the Food with Different Glycaemic Index and Glycaemic Load on the Immunity of Endurance Athletes. The Open Biomedical Engineering Journal, 9, pp.305–309.

Little, J.P., Chilibeck, P.D., Ciona, D., Forbes, S., Raes, H., Vandenberg, A., & Zello, G.A., 2010. Effect of Low- and High-Glycemic-Index Meals on Metabolism and Performance During High-Intensity, Intermittent Exercise. International Journal of Sport Nutrition and Exercise Metabolism, 20(6), pp.447–456.

Maughan, R.J., & Gleeson, M., 2010. The Biochemical Basis of Sports Performance. 2nd edn. Oxford: Oxford University Press.

Neves, P.R.D.S., Tenorio, T.R.D.S., Lins, T.A., Muniz, M.T.C., Curi, T.C.P., Botero, J.P., & Prado, W.L.D., 2015. Acute Effects of High- and Low-intensity Exercise Bouts on Leukocyte Counts. Journal of Exercise Science and Fitness, 13(1), pp.24–28.

Nieman, D.C., 2008. Immunonutrition Support for Athletes. Nutr Rev, 66(6), pp.310–320.

Ortenblad, N., Wasterblad, H., & Nielsen, J., 2013. Muscle Glycogen Stores and Fatigue. The Journal of Physiology, 591(18), pp.4405–4413.

Owen, A.L., Wong, D.P., Dunlop, G., Groussard, C., Kebsi, W., Dellal, A., Morgans, R., & Zouhal, H., 2016. High-intensity Training and Salivary Immunoglobulin: A Responses in Professional Top-level Soccer Players: Effect of Training Intensity. Journal of Strength and Conditioning Research, 30(9), pp.2460–2469.

Palmowski, J. Boblau, T.K., Ryl, L., Kruger, K., & Reichel, T., 2019. Managing Immune Health in Sports – A Practical Guide for Athletes and Coaches. Deutsche Zeitschrift fur Sportmedizin, 70(10), pp.219–226.

Rollo, I., 2014. Carbohydrate: The Football Fuel. Sport Science Exchange, 27(127), pp.1–8.

Siwi, T.P., Dieny, F.F., & Fitranti, D.Y., 2017. Pengaruh Diet dengan Pengaturan Indeks Glikemik dan Beban Glikemik Terhadap Kadar Glukosa Darah Atlet Sepak Bola Remaja. Jurnal Gizi Indonesia, 6(1), pp.1–8.

Terra, R., Silva, S.A.G.D., Pinto, V.S., & Dutra, P.M.L., 2012. Effect of Exercise on the Immune System: Response, Adaptation and Cell Signaling. Revista Brasileira de Medicina do Esporte, 18(3), pp.208–214.

Walsh, N.P., 2018. Recommendations to Maintain Immune Health in Athletes. Eouropean Journal of Sport Science. Taylor & Francis, 18(6), pp.820–831.

Wong, S.H.S., Siu, P.M., Lok, A., Chen, Y.J., Morris, J., & Lam, C.W., 2008. Effect of the Glycaemic Index of Pre-exercise Carbohydrate Meals on Running Performance. European Journal of Sport Science, 8(1), pp.23–33.

Ziaolhagh, S.J., & Naghibi, S., 2012. Effect of Pre-exercise Meals with Different Glycemic Indices on Cortisol and Circulating Leucocytes to an Endurance Performance Run in Male Athletes. European Journal of Experimental Biology, 2(6), pp.2251–2256.