Progress in Nutrition 2016; Vol. 18, N. 2: 95-101

Review

Glycemic index and glycemic load in cardiovascular disease risk

Dhananjay Yadav[1], *Meerambika Mishra*[2], *Pratiksha Jadaun*[3], *Eunhee Choi*[4], *R. Priyadharsini*[5], *In Deok Kong*[6]

[1]Department of Preventive Medicine, Wonju College of Medicine, Yonsei University Wonju, Korea; [2]School of Life Sciences, Sambalpur University, Jyoti Vihar, Burla, Odisha, India; [3]National AIDS Research Institute (NARI), Bhosari, Pune; [4]Institute of Lifestyle Medicine, Wonju College of Medicine, Yonsei University,Wonju, Korea; [5]Department of Pharmacology IGMCRI, Puducherry, India; [6]Department of Physiology Yonsei University Wonju College of Medicine, Korea - E-mail: kong@yonsei.ac.kr

Summary. Diet comprises of many nutritious components like carbohydrates, protein, fats and fibers. Each component has different functions which directly or indirectly involved in the growth and maintenance of the body. The behavioral modification of eating habits using high glycemic and glycemic load diet leads to certain changes in physiologic and biologic changes in an individual. This study discusses and summarizes the recent literature on high glycemic index/glycemic load carbohydrate diet and its pathological relationship in causing cardiovascular disease and its risk factors. High carbohydrate intake has an adverse effect on glucose and lipid metabolism, as a result of which may increase the risk of cardiovascular disease (CVD). A number of cohort studies examined the role of glycemic index and glycemic load on cardiovascular events. Randomized control trials and intervention studies support the hypothesis that high glycemic index and glycemic load diet could increase the risk of CVD in individuals with different outcomes in men and women. The inclusion of glycemic index and glycemic load in dietary recommendations may help in reducing the prevalence and incidence of cardiovascular disease and its risk factors.

Key words: glycemic index, glycemic load, randomized control trials, cardiovascular disease

Introduction

Carbohydrate in the form of glucose is the main fuel source that continuously supplies energy to all parts of our body. Basically, liver stores glucose in the form of glycogen, when the blood level of glucose goes below the normal range, glycogen is broken down into glucose for immediate energy. The different physiological response has been seen in the human body after consumption of carbohydrate-rich diet. Insulin is the important hormone which regulates the glucose level by maintaining the homeostasis between the production and utilization of glucose in different parts of the insulin-sensitive tissues and organs like adipose tissue, skeletal muscle, and liver. High intake of carbohydrate has an unfavorable effect on blood glucose and lipid profiles which cause hyperglycemia and hyperlipidemia which are recognized as a well- established risk factors for cardiovascular disease. Increased postprandial glucose and insulin level are a hallmark of insulin resistance state that is associated with elevated blood pressure and eventually metabolic syndrome (1-3).

Epidemiological and clinical studies suggest that high intake of carbohydrate is associated with several disturbances in the biochemical parameters in an individual which ultimately accelerates the risk of CVD (4-6). Glycemic index and glycemic load are used to compute the glycemic burden of carbohydrate from food reported in several studies (7-9). Although the importance of glycemic index and glycemic load are still needed to discuss in relation to risk of CVD and its factors. Therefore, our focus of this review is to highlight the importance of glycemic index. glycemic load in evaluating the risk association between dietary carbohydrate intake and cardiovascular risk and mortality. In the present scenario, evidence relating the glycemic index and glycemic load and their adverse relation with the CVD risk factor are scarce. Given that a startling increase in the prevalence of cardiovascular diseases worldwide, understanding the potential role of specific dietary factors such as glycemic index and load in preventing CVD risk has been a public health concern.

Definition of glycemic index and glycemic load

Glycemic index is a practical basis for classifying dietary carbohydrate, that was first described by Jenkins et al. (10) and also an alternative system to distinguish carbohydrate containing food based on their glycemic response. Glycemic index is calculated by area covered by blood glucose within 2 hrs post-consumption of 50g available carbohydrate divided by the same amount of control food, multiplied by 100% (7). A food that possess high glycemic index (>70) causes a quick rises in the blood glucose concentration while a low glycemic index (<55) food cause a slower and more sustained release of glucose into the blood (11). However, evidence of the clinical value of low-glycemic index diet, still awaits prospective trials. Glycemic index depends on the amount of carbohydrate intake, the nature of food and physical activity that may influence on the meal of individual and additionally, other factors are also responsible for individual variations.

Glycemic load is yet another variable used largely for quantifying the glycemic effect of carbohydrate from food (12). Glycemic load is the product of glycemic index and the total available carbohydrate content in a particular amount of food (1, 13). Glycemic load is a glycemic index-weighted measure of carbohydrate content representing both quality and quantity. For example, watermelon has a high glycemic index, but with low carbohydrate content, thus it has a low glycemic load of eating. In contrast with fructose, which has a low glycemic index, but having high glycemic load. Glycemic load can be calculated for any size serving of a food, an entire meal, or an entire day's meals. The glycemic load greater than 20 is considered high, a glycemic load of 11-19 is considered average, and ≤ 10 of glycemic load is considered as low (14). The foods which have a low glycemic load having typical serving size almost have a low glycemic index. Foods with an intermediate or high glycemic load range from a very low to very high glycemic index serving size. The amount of indigestible oligosaccharide or starches containing food has lower overall glycemic load because these macronutrients do not affect blood glucose concentrations. It has been studied that glycemic load appears to be beneficial in dietary programs coursing metabolic syndrome, weight loss, and insulin resistance. The value of glycemic index and glycemic load mainly represents the postprandial phase of blood glucose. Therefore, dietary counseling proves vital for the diabetics and non-diabetic individuals to help lower their postprandial level of glycemia and insulin levels (15).

Glycemic index, glycemic load, and gender difference in the burden of cardiovascular disease

The issue of glycemic index and glycemic load has caught recent attention because of the boost in carbohydrate consumption and introduction of the modern milling technology lessens the potential health benefits of grains (16, 17). Lan-Pidhainy and Wolever (18) demonstrated that the glycemic index is an important attribute of a food because it shows similar results for healthy control as well as for type 2 diabetics. The detrimental effect of glycemic index was shown by Jakobsen et al. in a prospective cohort study suggested that replacement of the saturated fatty acids with high dietary glycemic index significantly elevated the risk of myocardial infarction (relative risk per 5% increase EA of energy from carbohydrates: 1.33; 95% CI: 1.08, 1.64) (19).

Epidemiological studies reported that high dietary glycemic index and glycemic load may have an adverse effect in relation to the risk of coronary heart disease (CHD) (20-22). Fan et al. studied meta-analysis of 15 observational studies and investigated that high dietary glycemic load was associated with a higher risk of CHD and stroke (22). However, dietary glycemic index related with the risk of CHD only. Few studies also reported the impact of body weight on the relations of glycemic index and glycemic load to CHD risk (23, 24). Oba et al. and Kaushik et al. published data related to the risk of stroke and stroke-associated mortality, in participants consuming high glycemic index and glycemic load. However, suggested a lack of conclusive findings (25, 26). Hardy et al. revealed by a prospective cohort of 13,051 patients ages 45 to 64 years, over a maximum of 17 years of follow-up 1683 cases of CHD were recorded, which exhibited a significant 16% increased risk for CHD per 5-unit increment in dietary glycemic index in African Americans, however in whites the association was seen only in GL (30-unit increase in glycemic load showed an 11% increase in CHD) (27). Studies in human and animal models have exhibited the influence of high glycemic index diet on appetite and its involvement in promoting weight gain (28). Another study conducted in White and African-American population with and without type 2 diabetes to unravel the association of high glycemic index and glycemic load diet with the incident risk of CHD (27). The study recommended reduction of the glycemic index/glycemic load in the diet to attain a reduced CHD risk.

Epidemiological studies have suggested a gender-related variation of glycemic index/glycemic load and risk of mortality from stroke (25) in the Japanese population. The study implied that a diet with a high dietary glycemic index added to the risk of mortality among women from stroke. Unlike to above study of myocardial infarction in Finnish men was published by Mursu et al. (23) emphasized the usefulness of glycemic index and glycemic load in predicting myocardial infarction. The EPICOR study in Italian cohort (29) reported a distinctive association with high glycemic index/glycemic load diet and the risk of CVD in women whereas not in men. Additionally, this study noticed that food having glycemic index>57 is significantly associated with the increased risk of CHD after 8 years of follow-up study.

Recently Dong et al. & Mirrahimi et al. reported from a meta-analysis of prospective studies that high dietary glycemic load and glycemic index significantly increased the risk of CHD events in women only (8, 30). The former study suggested that participants with the highest level of dietary glycemic index and glycemic load had approximately 1.3-fold increased risk of CHD in women but was not shown in men when compared with the lowest level of glycemic index and glycemic load. Knopp et al. suggested that the response produced by high glycemic diet in women had significantly decreased HDL-cholesterol levels and elevated triglyceride concentration compared to men (31). Therefore, more studies are needed to perceive the relationship of gender differences, different ethnic backgrounds and other confounding factors that relate to glycemic index/glycemic load in developing CVD.

Dietary glycemic index and glycemic load and CVD risk factors

Previous studies have tended to uncover that high glycemic index diet were associated with higher insulin level (32, 33) and elevates the risk of developing diabetes in future (34, 35). The increasing incidence of diabetes highlights its importance on the burden of CVD (36). McKeown et al. (33) found a positive association of both glycemic index and glycemic load with homeostasis model assessment-estimated insulin resistance (HOMA-IR) that was independent of energy intake. On contrary Lau's team (37) found no evidence for links between glycemic index and HOMA-IR but reported its association with the glycemic load after adjusting for fiber.

Jenkins et al. reported that the consumption of high glycemic index food compared to isoenergetic and controlled low glycemic index food in non-diabetic individuals results in high blood glucose, insulin level, high C-peptide and higher glycosylated hemoglobin (38). The reason accounted for this was the rapid absorption of glucose after consumption of high glycemic index meal which alters the homeostasis mechanism particularly the beta cell function for postprandial to the post-absorptive state (39). In the initial 2 hrs post-consumption of high- glycemic index diet, the incremental area under glucose response was seen to be twice than that of a lower glucose index food, with high insulin and glucagon ratio. During the late postprandial phase, the counterregulatory hormones (glucagon, epinephrine, cortisol and growth hormone) restore euglycemia after a high glycemic index meal and cause a significant increase in the free fatty acid concentration (Fig. 1). Varied physiological response have been seen after the consumption of low and high glycemic index food, however, a substantial amount of further randomized control trial is mandated to clinically prove its relation with CVD risk factor that gets accelerated after intake of high glycemic index diet.

Observational studies among European and US population have shown an abnormal value in lipid profile, especially low HDL-cholesterol and high triglyceride level in the upper quintile of dietary glycemic index or glycemic load (40, 41). Romaguera et al. (42) professed that glycemic index is related to waist circumference and BMI which is a marker of adiposity and possibly another crucial factor that links dietary glycemic index with CHD incidence. Recently, two cross-sectional studies reported the association between body weight and glycemic index, glycemic load in children, adolescents, and adults respectively. This study evaluated that glycemic load was independently associated with overweight in children and with central obesity in adolescents (43). An independent positive association of dietary glycemic index and glycemic load with general and central obesity in British adults was also evaluated by the same group (44).

Willett et al. evaluated that the effect of high glycemic diet, importantly change in an individual reliably on their level of adiposity, that aggravates insulin resistance and dysfunction in lipid profile leading to higher risk of CHD incidence (14). Figure 1 represents a hypothetical flow chart which may describe how high glycemic/glycemic load diet may increase the risk factors for developing CVD (7, 45). A number of different components involve such as insulin resistance, free fatty acid, inflammation and endothelial

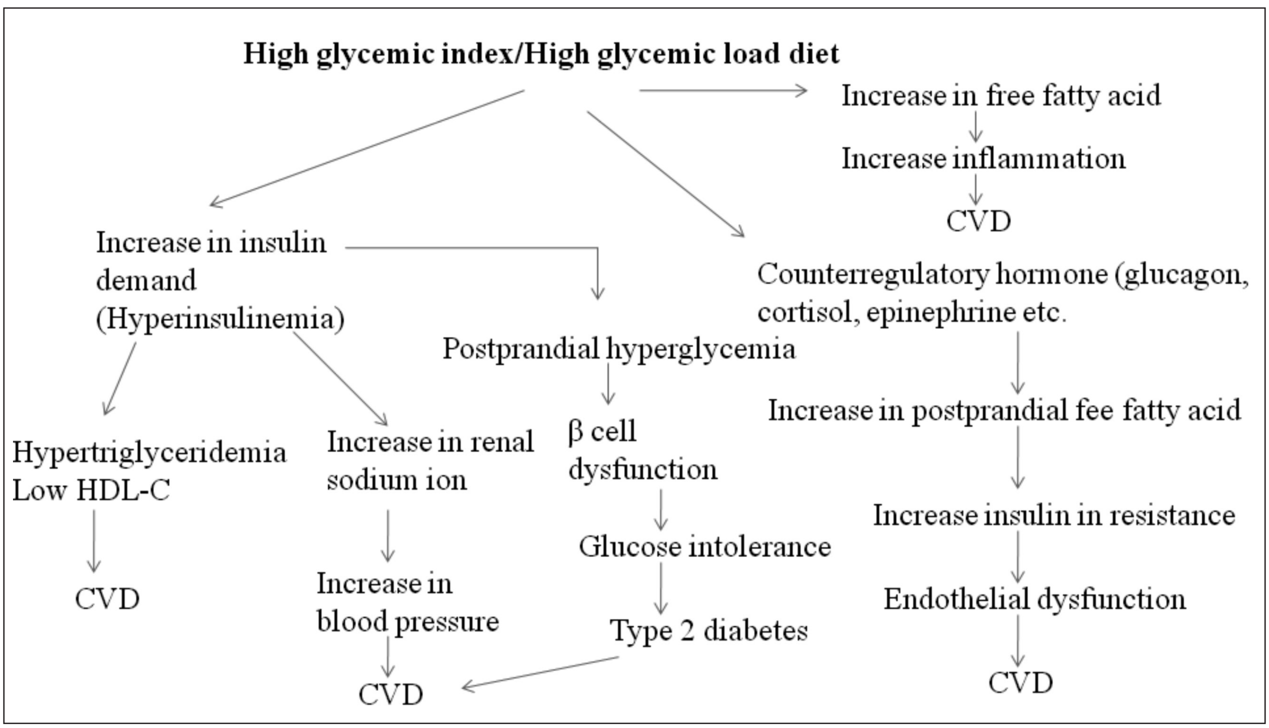

Figure 1. Hypothetical flow chart relates high intake of glycemic index/glycemic load diet increases the risk of cardiovascular disease (Modified from Radulian et al., 2009 & Ludwig, 2002)
Consumption of carbohydrate rich diet leads to glucose intolerance and insulin resistance that play a key role in developing many pathological conditions. Hyperinsulinemia condition elevates triglyceride formation in the liver and further progress to dyslipidemia which is a vital risk factor for CVD. High level of insulin increases renal sodium reabsorption ion in the kidney and cause hypertension. High glycemic diet increases the inflammation by activating inflammatory cytokines. Lastly, counter regulatory hormone, postprandial free fatty acid and endothelial dysfunction have a role in developing CVD.

dysfunction which could aggravate the risk of CVD. It has also been evaluated that consumption of high glycemic index and or glycemic index load is synonymous with the higher level of C-reactive protein, along with decreased level of adiponectin which ultimately activates proinflammatory activities (46, 47). Moreover, a recent cohort study investigated that the highest quartile of glycemic index was associated with significantly elevated levels of TNF-alpha and IL-6 compared with the lowest quartile of dietary glycemic index. The above study demonstrated the association between high glycemic index and systemic inflammation (48).

The consumption of low glycemic index/glycemic load diet has crucial role in reducing the risk factors of CVD. Foster and team investigated a randomized controlled trial for one year and recruited 63 obese individuals with either low carbohydrate diet or low-fat diet. In low carbohydrate group, weight loss had been seen after 6 months but was not found to be significant after the completion of study time period but showed a decrease in the triglyceride level and improved HDL cholesterol level (49). The beneficial effect of low glycemic index diet on triglyceride levels in subjects with type 2 diabetes was reported in Canadian trial of carbohydrates study (50).

Miller and co-workers (51) published a meta-analysis of randomized controlled trial comparing low and high glycemic index diet and observed that glycated protein was reduced to 7.6% in the low glycemic index diet group. However, it should also be noted that results of many epidemiological studies are contradictory due to the interaction of many confounding variable and most studies focused on the glycemic index and glycemic load calculation based on the quantitative or self-reporting. It depends on various aspects like portion size and recall bias leading to inaccurate reporting (52). The method of food preparation and different forms of the same foods (white rice, brown rice) changes the glycemic index of food, hence should be taken into consideration while calculating glycemic index or glycemic load of carbohydrate containing foods. Future observational studies and randomized control trials are needed to focus on the precise mechanism through which glycemic index or glycemic load might effect in reducing the risk of CVD and its factors.

Conclusion

The consumption of a carbohydrate-rich diet adversely affects and leads to severe changes in lipid and glucose parameters that substantially elevate the risk factors for CVD. Our review summarizes an evidence of association between glycemic index/ glycemic load and risk of CVDs. The inclusion of glycemic index and glycemic load in dietary recommendations may help in reducing the prevalence and incidence of this deadly disease. Sexual differences in CVD response to glycemic index/glycemic load in several meta-analyses indicated to address its underlying cause. It is requisite for the physicians and researchers to consider the importance of low glycemic index/glycemic load in epidemiological studies as well as during dietary advice. Large observational studies are needed to understand the impact of high and low glycemic index or glycemic load diet to monitor the risk and health benefits.

References

1. Mirrahimi A, Chiavaroli L, Srichaikul K et al. The role of glycemic index and glycemic load in cardiovascular disease and its risk factors: a review of the recent literature. Curr Atheroscler Rep 2014; 16: 381.
2. Ceriello A, Davidson J, Hanefeld M et al. Postprandial hyperglycaemia and cardiovascular complications of diabetes: an update. Nutr Metab Cardiovasc Dis 2006; 16: 453-6.
3. Leiter LA, Ceriello A, Davidson JA et al. Postprandial glucose regulation: new data and new implications. Clin Ther 2005; 27 Suppl B: S42-56.
4. Jeppesen J, Schaaf P, Jones C, Zhou MY, Chen YD, Reaven GM. Effects of low-fat, high-carbohydrate diets on risk factors for ischemic heart disease in postmenopausal women. Am J Clin Nutr 1997; 65: 1027-33.
5. Mann J. Dietary carbohydrate: relationship to cardiovascular disease and disorders of carbohydrate metabolism. Eur J Clin Nutr 2007; 61 Suppl 1: S100-11.
6. Siri-Tarino PW, Sun Q, Hu FB, Krauss RM. Saturated fat, carbohydrate, and cardiovascular disease. Am J Clin Nutr 2010; 91: 502-9.
7. Ludwig DS. The glycemic index: physiological mechanisms relating to obesity, diabetes, and cardiovascular disease. JAMA 2002; 287: 2414-23.
8. Dong JY, Zhang YH, Wang P, Qin LQ. Meta-analysis of dietary glycemic load and glycemic index in relation to risk of coronary heart disease. Am J Cardiol 2012; 109: 1608-13.
9. Ma XY, Liu JP, Song ZY. Glycemic load, glycemic index and risk of cardiovascular diseases: meta-analyses of prospective

studies. Atherosclerosis 2012; 223: 491-6.
10. Jenkins DJ, Wolever TM, Taylor RH et al. Glycemic index of foods: a physiological basis for carbohydrate exchange. Am J Clin Nutr 1981; 34: 362-6.
11. Lunn J, Buttriss JL. Carbohydrates and dietary fibre. Nutrition Bulletin 2007; 32: 21-64.
12. Kuo Y-C, Lin J-C, Bernard JR, Liao Y-H. Green tea extract supplementation does not hamper endurance-training adaptation but improves antioxidant capacity in sedentary men. Applied Physiology, Nutrition, and Metabolism 2015; 40: 990-6.
13. Atkinson FS, Foster-Powell K, Brand-Miller JC. International tables of glycemic index and glycemic load values: 2008. Diabetes Care 2008; 31: 2281-3.
14. Willett W, Manson J, Liu S. Glycemic index, glycemic load, and risk of type 2 diabetes. Am J Clin Nutr 2002; 76: 274S-80S.
15. Brand-Miller J, Buyken AE. The glycemic index issue. Curr Opin Lipidol 2012; 23: 62-7.
16. Misra A, Rastogi K, Joshi SR. Whole grains and health: perspective for Asian Indians. J Assoc Physicians India 2009; 57: 155-62.
17. Mohan V, Radhika G, Sathya RM, Tamil SR, Ganesan A, Sudha V. Dietary carbohydrates, glycaemic load, food groups and newly detected type 2 diabetes among urban Asian Indian population in Chennai, India (Chennai Urban Rural Epidemiology Study 59). Br J Nutr 2009; 102: 1498-506.
18. Lan-Pidhainy X, Wolever TM. Are the glycemic and insulinemic index values of carbohydrate foods similar in healthy control, hyperinsulinemic and type 2 diabetic patients? Eur J Clin Nutr 2011; 65: 727-34.
19. Jakobsen MU, Dethlefsen C, Joensen AM et al. Intake of carbohydrates compared with intake of saturated fatty acids and risk of myocardial infarction: importance of the glycemic index. Am J Clin Nutr 2010; 91: 1764-8.
20. Beulens JW, de Bruijne LM, Stolk RP et al. High dietary glycemic load and glycemic index increase risk of cardiovascular disease among middle-aged women: a population-based follow-up study. J Am Coll Cardiol 2007; 50: 14-21.
21. Liu S, Willett WC, Stampfer MJ et al. A prospective study of dietary glycemic load, carbohydrate intake, and risk of coronary heart disease in US women. Am J Clin Nutr 2000; 71: 1455-61.
22. Fan J, Song Y, Wang Y, Hui R, Zhang W. Dietary glycemic index, glycemic load, and risk of coronary heart disease, stroke, and stroke mortality: a systematic review with meta-analysis. PLoS One 2012; 7: e52182.
23. Mursu J, Virtanen JK, Rissanen TH et al. Glycemic index, glycemic load, and the risk of acute myocardial infarction in Finnish men: the Kuopio Ischaemic Heart Disease Risk Factor Study. Nutr Metab Cardiovasc Dis 2011; 21: 144-9.
24. Levitan EB, Mittleman MA, Wolk A. Dietary glycaemic index, dietary glycaemic load and incidence of myocardial infarction in women. Br J Nutr 2010; 103: 1049-55.
25. Oba S, Nagata C, Nakamura K et al. Dietary glycemic index, glycemic load, and intake of carbohydrate and rice in relation to risk of mortality from stroke and its subtypes in Japanese men and women. Metabolism 2010; 59: 1574-82.
26. Kaushik S, Wang JJ, Wong TY et al. Glycemic index, retinal vascular caliber, and stroke mortality. Stroke 2009; 40: 206-12.
27. Hardy DS, Hoelscher DM, Aragaki C et al. Association of glycemic index and glycemic load with risk of incident coronary heart disease among Whites and African Americans with and without type 2 diabetes: the Atherosclerosis Risk in Communities study. Ann Epidemiol 2010; 20: 610-6.
28. Brand-Miller JC, Holt SH, Pawlak DB, McMillan J. Glycemic index and obesity. Am J Clin Nutr 2002; 76: 281s-5s.
29. Sieri S, Krogh V, Berrino F et al. Dietary glycemic load and index and risk of coronary heart disease in a large italian cohort: the EPICOR study. Arch Intern Med 2010; 170: 640-7.
30. Mirrahimi A, de Souza RJ, Chiavaroli L et al. Associations of glycemic index and load with coronary heart disease events: a systematic review and meta-analysis of prospective cohorts. J Am Heart Assoc 2012; 1: e000752.
31. Knopp RH, Paramsothy P, Retzlaff BM et al. Gender differences in lipoprotein metabolism and dietary response: basis in hormonal differences and implications for cardiovascular disease. Curr Atheroscler Rep 2005; 7: 472-9.
32. van Dam RM, Visscher AW, Feskens EJ, Verhoef P, Kromhout D. Dietary glycemic index in relation to metabolic risk factors and incidence of coronary heart disease: the Zutphen Elderly Study. Eur J Clin Nutr 2000; 54: 726-31.
33. McKeown NM, Meigs JB, Liu S, Saltzman E, Wilson PW, Jacques PF. Carbohydrate nutrition, insulin resistance, and the prevalence of the metabolic syndrome in the Framingham Offspring Cohort. Diabetes Care 2004; 27: 538-46.
34. Salmeron J, Ascherio A, Rimm EB et al. Dietary fiber, glycemic load, and risk of NIDDM in men. Diabetes Care 1997; 20: 545-50.
35. Schulze MB, Liu S, Rimm EB, Manson JE, Willett WC, Hu FB. Glycemic index, glycemic load, and dietary fiber intake and incidence of type 2 diabetes in younger and middle-aged women. Am J Clin Nutr 2004; 80: 348-56.
36. Fox CS. Cardiovascular disease risk factors, type 2 diabetes mellitus, and the Framingham Heart Study. Trends Cardiovasc Med 2010; 20: 90-5.
37. Lau C, Faerch K, Glumer C et al. Dietary glycemic index, glycemic load, fiber, simple sugars, and insulin resistance: the Inter99 study. Diabetes Care 2005; 28: 1397-403.
38. Jenkins DJ, Wolever TM, Collier GR et al. Metabolic effects of a low-glycemic-index diet. Am J Clin Nutr 1987; 46: 968-75.
39. Ludwig DS, Majzoub JA, Al-Zahrani A, Dallal GE, Blanco I, Roberts SB. High glycemic index foods, overeating, and obesity. Pediatrics 1999; 103: E26.
40. Finley CE, Barlow CE, Halton TL, Haskell WL. Glycemic index, glycemic load, and prevalence of the metabolic syndrome in the cooper center longitudinal study. J Am Diet Assoc 2010; 110: 1820-9.
41. Du H, van der AD, van Bakel MM et al. Glycemic index and glycemic load in relation to food and nutrient intake and metabolic risk factors in a Dutch population. Am J Clin Nutr 2008; 87: 655-61.

42. Romaguera D, Angquist L, Du H et al. Dietary determinants of changes in waist circumference adjusted for body mass index - a proxy measure of visceral adiposity. PLoS One 2010; 5: e11588.
43. Murakami K, McCaffrey TA, Livingstone MB. Dietary glycaemic index and glycaemic load in relation to food and nutrient intake and indices of body fatness in British children and adolescents. Br J Nutr 2013; 110: 1512-23.
44. Murakami K, McCaffrey TA, Livingstone MB. Associations of dietary glycaemic index and glycaemic load with food and nutrient intake and general and central obesity in British adults. Br J Nutr 2013; 110: 2047-57.
45. Radulian G, Rusu E, Dragomir A, Posea M. Metabolic effects of low glycaemic index diets. Nutr J 2009; 8: 5.
46. Qi L, Hu FB. Dietary glycemic load, whole grains, and systemic inflammation in diabetes: the epidemiological evidence. Curr Opin Lipidol 2007; 18: 3-8.
47. Loh BI, Sathyasuryan DR, Mohamed HJ. Plasma adiponectin concentrations are associated with dietary glycemic index in Malaysian patients with type 2 diabetes. Asia Pac J Clin Nutr 2013; 22: 241-8.
48. Bullo M, Casas R, Portillo MP et al. Dietary glycemic index/load and peripheral adipokines and inflammatory markers in elderly subjects at high cardiovascular risk. Nutr Metab Cardiovasc Dis 2013; 23: 443-50.
49. Foster GD, Wyatt HR, Hill JO et al. A randomized trial of a low-carbohydrate diet for obesity. N Engl J Med 2003; 348: 2082-90.
50. Wolever TM, Gibbs AL, Chiasson JL et al. Altering source or amount of dietary carbohydrate has acute and chronic effects on postprandial glucose and triglycerides in type 2 diabetes: Canadian trial of Carbohydrates in Diabetes (CCD). Nutr Metab Cardiovasc Dis 2013; 23: 227-34.
51. Brand-Miller J, Hayne S, Petocz P, Colagiuri S. Low-glycemic index diets in the management of diabetes: a meta-analysis of randomized controlled trials. Diabetes Care 2003; 26: 2261-7.
52. Pi-Sunyer FX. Glycemic index and disease. Am J Clin Nutr 2002; 76: 290s-8s.

Correspondence:
In Deok Kong
Department of Physiology Yonsei University Wonju College of Medicine, Korea
E-mail: kong@yonsei.ac.kr