Dietary intakes and leptin concentrations
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Abstract
BACKGROUND: Leptin, a peptide contained 146 amino-acids, is mostly secreted from adipose tissue and it has a critical role on regulation of body weight and body fat mass. We tried to review the previous evidence regarding the effects of dietary intakes, including consumption of carbohydrates, fats and protein on concentrations of leptin concentration.

METHODS: We searched in PubMed search engine to January 2013 by using the following key words: dietary intake, diet, dietary fat, high-fat diet, dietary carbohydrate, high carbohydrate diet, dietary protein, high protein diet in combination with leptin, adipokine. Then, we recruited 35 articles to review in the present study.

RESULTS: It seems that beside the amount of fats, type of fatty acids have the key roles on circulating leptin concentration. Energy intake also significantly associated with the hormone. Studies regarding the association between carbohydrate intake and concentration of lepton have been reached to contradictory results. It seems that protein intake can increase the lepton activity.

CONCLUSION: Findings from several studies suggest that a diet display an important role on change the concentration of lepton.

Keywords: Diet, Carbohydrate, Protein, Fat, Leptin

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Introduction
Leptin, a 16 kDa protein, is a peptide contained 146 amino-acids that are discovered in 1994. Leptin is mostly secreted from adipose tissue, and it has a critical role on regulation of body weight and also body fat mass.1-3 It markedly regulates energy expenditure, appetite, thermogenesis and food intakes. Leptin caused to increase fatty acids oxidation and decrease triglyceride synthesis and so that it attenuates lipogenic action of insulin and increases insulin sensitivity of muscle and liver. This hormone has the favorable effect on glucose homeostasis.4-7 Given the key role of leptin on regulation of body weight and prevention of obesity, it seemed that leptin levels were decreased during the elevation of body weight.8 But according to a large body of evidence, most obese humans have higher circulations of leptin.9 It has been indicated that obesity might induces state of leptin resistance.10 Inactivation of leptin receptors enhance leptin resistance and reduces satiety, and it enhances the risk of obesity.5 Therefore, treatment of obesity tends to increase leptin action in central nervous system (CNS), which is able to decrease food intake and body fat through the reduction of energy intakes.1,5,8

Expression and secretion of leptin is enhanced by estrogen, tumor necrosis factor-α, corticosteroids as well as glucose and insulin. In contrast, T₄, growth hormone, catecholamine, androgens and free fatty acids suppress the expression of this hormone.11,12 Among these parameters, diet-related factors display the important roles on augmentation and amelioration of this hormone.13-19 Among diet-related factors, dietary components including consumption of beverages, fatty acids, proteins and carbohydrates have been shown to have a significant association with concentrations of leptin.1,15,20,22 However, contradictory results are found in this regard. Based on several evidence diets rich in polyunsaturated fatty acids (PUFA) (ɷ₃ and ɷ₆) leads to increase circulating of leptin compared to diet rich in monounsaturated fatty acids (MUFA) and saturated fatty acids (SFA).20 In contrast, according to some studies consumption of ɷ₃ fatty acids showed a reduction in leptin gene expression.23,24 High carbohydrate diet might
increase leptin sensitivity in some studies.\textsuperscript{5,8} Beside percent consumption of carbohydrate, glycemic index and glycemic load of carbohydrate also have been indicated to have a critical role on concentrations of leptin.\textsuperscript{16}

In this review article, we tried to review the previous evidence regarding the effects of dietary intakes, including consumption of carbohydrates, fats and protein on concentrations of leptin and also explain about potential underlying mechanism in this regard.

**Materials and Methods**
To investigate the relationship between dietary

| Study | Type of study | Numbers/sex | Age (year)/BMI | Design and aim | Duration of study | Results |
|-------|---------------|-------------|----------------|----------------|------------------|---------|
| 1     | Parallel      | 55 obese men and women | Age: 25.7 ± 5.4
BMI: 23.0 ± 2.3 | Effect of diets with 3 types of fat (olive, rapeseeds, sunflower oil) | 2 weeks diet with SFA and 4 intervention diets | Serum levels of leptin effect on diet rich in α-linoleic acids |
| 6     | Parallel      | 18 women and men | Age: 45.3 ± 13.6
BMI: 27.1 ± 2.3 | Effect of high carbohydrate low fat on serum level of leptin (35% fat, 45% CHO, 20% protein) compared to (15% fat, 65% CHO, 20% protein) | 2 weeks weight maintenance, 2 weeks isocaloric and 12 weeks weight loss diet | No change was found in level of leptin and increase in leptin sensitivity |
| 8     | Cross sectional | 31 (women and men) cirrhosis patients and 10 controls | Age: 54-57
BMI: 25.7-56.5 | Assessing the association between energy intakes and leptin | - | No significant relationship was found |
| 9     | Parallel      | 19 lean and obese women | Age: 21.5 ± 1.9
BMI: 21.6 ± 1.8
Age: 34.6 ± 7.8
BMI: 49.8 ± 6.9 | Isocaleric meals: 166 g CHO, 38 g protein and 70 g fat, 36 g protein | 2 weeks normal diet with weight maintenance 2 weeks isocarelie high protein diet, 12 weeks high protein weight loss diet | Significant lower levels of leptin after carbohydrate meals in obese women compared to lean women |
| 16    | Parallel      | 19 women and men | Age: 41 ± 11
BMI: 26.2 ± 2.1 | Effect of high protein diet on leptin (50% CHO, 35% fat, 15% protein) compared to (50% CHO, 20% fat, 30% protein) | - | Greater status of satiety with no change in plasma leptin after high protein diet |
| 17    | Cross sectional | 165 healthy overweight and obese women in postmenauposal status | Age: 60.73 ± 6.7
BMI: 30.5 ± 3.9 | Assessing the association between habitual dietary intakes and leptin | - | Inverse relationship between consumption of high carbohydrate and fat with hormone |
| 18    | Parallel      | 13 lean and overweight men | Age: 18-27
BMI: 20.8 ± 0.7
30.8 ± 1.7 | High carbohydrate, low fat meals (80% CHO, 17% protein, 3% fat) | 3 days | No significant difference was found |
| 19    | Parallel      | 200 women | Age: 100 women with ≤ 50
BMI: 25.7 | Diet rich in fruits, vegetables and fiber with low amount of fat | 12 months | Had no effect on leptin |
Table 1. Studies regarding the association between dietary intakes and concentrations of leptin (Continue)

| Study | Type of study | Numbers/sex | Age (year)/BMI | Design and aim | Duration of study | Results |
|-------|---------------|-------------|----------------|----------------|-------------------|---------|
| 20    | Cross sectional | 60 men and women with Type 1 diabetes | Age: 22.8 ± 6.8 BMI: 22.7 ± 2.3 | Assessing the association between consumption of SFA and PUFA and leptin | - | Positive relationship with consumption of SFA and leptin in men/ positive and negative association between linolenic acid and arachidonic acids and leptin, respectively |
| 25    | Experimental | 344 female rats | - | High fat diet in comparison with low fat with complex carbohydrate | 20 months | Increase in plasma level of hormone by the high fat diet |
| 26    | Cross over | 9 men and women | Age: 20-37 BMI: 18-26 | High carbohydrate diet with different in glycemic index and fat in 4 groups | 8 days | 17% greater in diets with high glycemic index |
| 27    | Experimental | rats | - | Effect of type of fat in low calorie diet on leptin | 10 weeks | 60% increase in leptin concentration among fish oil and sunflower oil fed compared to beef tallow fed |
| 28    | Cross sectional | 211 male and 205 female of Japanese-American in Hawaii and Japanese in Japan | Age: 40-59 BMI: < 25 and ≥ 25 | Assessing the association between energy intake and serum leptin concentration | - | Inverse relationship between energy intake and serum level of leptin in obese persons |
| 29    | Parallel | 44 healthy male | Age: 43 ± 5 BMI: 27.3 ± 3.2 | Effect of low calorie diet on plasma leptin | 4 days | 39.4% decrease in leptin by the energy restricted diet |

BMI: Body mass index; PUFA: Polyunsaturated fatty acid; SFA: Saturated fatty acid; CHO: Carbohydrate

**Results**

Carbohydrate intake and concentrations of leptin: results from studies evaluated the association between adherence to high carbohydrate diet and leptin concentration have been shown to reach contradictory results.\(^5,6,16,17,30\)

Consumption of carbohydrate with high glycemic load may leads to leptin resistance.\(^6,17\) However, consumption of the high amount of fiber and high carbohydrate diet were found to have a decreased concentration of leptin and increase in insulin sensitivity, respectively.\(^5,8,16\) One crossover clinical trial study conducted among 9 healthy individuals indicated that high glycemic index carbohydrate diet increased diurnal rhythm of leptin.\(^7\) Consumption of 80% carbohydrate in 13 lean and overweight men had not shown a significant difference in concentration of leptin. However, oxidation of carbohydrate was substantially lower in obese subjects that may be due to leptin resistance in obese individuals.\(^17\)

One parallel intervention study conducted among 18 men and women individuals suggested that adherence to high carbohydrate diet [65% carbohydrate (CHO), 15% fat, 20% protein] had not significant effect on concentration of leptin in comparison with subjects consumed control diet (45% CHO, 30% fat, 20% protein). This diet enhanced leptin sensitivity.\(^5\) It seems that leptin response implicate after consumption of carbohydrate meals among obese subjects.\(^8,17\) One cross-sectional study conducted among 165 overweight and obese women, in the age range of 50-75 years, showed that significant inverse association between consumption of habitual high carbohydrate and fat intakes and leptin concentration after adjustment for potential confounders (\(\beta = -0.11, P = 0.04\)).\(^16\) Adherence to diet rich in fruits, vegetables and fiber with lower amounts of fat during 12 months had not showed the substantial effect on leptin level in healthy women.\(^18\)

Fats intake and leptin levels: most studies regarding the relationship between high-fat diet and concentration of leptin were found that there is a positive association between intake of higher fats and leptin level.\(^8,31\) Furthermore, type of fats including SFA, MUFA and PUFA play the key roles on augmentation or reduction of circulating leptin concentration.\(^1,19,21,25\) However, contradictory results were observed in this regard.\(^14,26\)

One cross-sectional study conducted among
individuals with type 1 diabetes had shown that men consumed more SFA had more concentration of leptin.\textsuperscript{19} Consumption of linoleic acid and arachidonic acids among women had a positive and negative correlation with serum levels of leptin, respectively.\textsuperscript{19} In one parallel clinical trial conducted among 55 obese subjects, adherence to diet rich in α-linolenic acid source (rapeseed oil) in 4 weeks led to increase in serum level of leptin compared with individuals who followed the diet rich in MUFA and ω6 sources (olive oil and sunflower oil, respectively).\textsuperscript{1} High-fat diet substantially enhanced plasma level of leptin in rats.\textsuperscript{31} In one parallel intervention study, consumption of the meal with 70 g fat and 36 g protein showed no significant change in postprandial leptin among 19 lean and obese women compared to high carbohydrate diet.\textsuperscript{8} In one experimental study rats, fed fish oil and safflower oil energy restricted diet had 62% reduction in leptin levels compared to beef tallow fed.\textsuperscript{21} In contrast, energy-restricted diet independent of the type of fats could increase leptin production in rats.\textsuperscript{14} Protein intake and leptin levels: fewer studies examining the effect of high protein diet on leptin concentration.\textsuperscript{13,15} It seems that high protein low-caloric diet tend to increase in leptin activity.\textsuperscript{15} Results from one parallel clinical trial conducted among 19 participants (men and women) indicated that adherence to high protein diet (30\% protein) in 2 weeks of iso-caloric diet did not enhance the area under curve (AUC) of leptin compared to control diet (15\% protein). Furthermore, leptin AUC markedly decreased during 12 weeks energy restricted high protein diet.\textsuperscript{13} It seems that higher protein intake could increase leptin sensitivity despite any increase in the hormone concentration.\textsuperscript{13} Augmentation of high dietary protein during second trimester of gestation led to significantly increase plasma level of leptin in one experimental study.\textsuperscript{13} Results from other experimental investigation found no substantial effect of high protein diet on serum level of leptin.\textsuperscript{27}

One intervention study conducted among 17 non-diabetic male suggested that low protein diet (0.6 g/kg) decrease plasma level of leptin that not to be mediated through insulin-related mechanism.\textsuperscript{32} In contrast, serum leptin concentration was markedly greater in rats with low protein diet, and food intake enhanced due to augmentation of leptin in one experimental study.\textsuperscript{33} Increase of leptin concentration suggested that low protein diet might lead to the state of leptin resistance.\textsuperscript{33}

Energy intake and concentration of leptin: it seems that energy restriction reduces concentration of leptin and high energy intake induces state of leptin resistance.\textsuperscript{5,34,35} A cross-sectional study conducted among a sample of patients with liver cirrhosis showed that there is an inverse relationship between fasting leptin and resting energy expenditure. Energy intake was found to have no substantial correlation with fasting concentration of leptin.\textsuperscript{7} Serum level of leptin was substantially negatively correlated with dietary energy intake in obese individuals in one cross-sectional study among a sample of Japanese-American in Hawaii and Japanese in Japan.\textsuperscript{34} One intervention study conducted among 44 healthy men suggested that energy restricted diet decreased 39.4\% fasting leptin concentration.\textsuperscript{35}

Discussion

Findings from several studies suggest that a diet display an important role on change the concentration of leptin.\textsuperscript{5,8,15} It seems that beside the amount of fats, type of fatty acids have the key roles on circulating leptin concentration.\textsuperscript{12} Energy intake also significantly associated with the hormone.\textsuperscript{34,35} Carbohydrate intake has an important role on regulation of leptin level that may be due to change in insulin secretion.\textsuperscript{8} It is supported by evidence that carbohydrate meal induces greater postprandial leptin concentrations than fat meal.\textsuperscript{28} According to evidence leptin deficiency leads to state of obesity, as well as insulin resistance and glucose tolerance impairment.\textsuperscript{29} In the other hand, obese subjects have more concentration of leptin that tends to be the state of leptin resistance.\textsuperscript{36} In addition, concentration of leptin implicates in subjects with Types 1 and 2 diabetes.\textsuperscript{37,38} Obesity is one of the important factors in the etiology of metabolic syndrome, diabetes and cardiovascular diseases.\textsuperscript{39,41} and dietary intakes have the important role on controlling the obesity and chronic diseases.\textsuperscript{31} Consumption of high glycemic load of carbohydrates enhance concentration of the hormone.\textsuperscript{6} In addition, intake of the high amount of fiber causes to increase the leptin sensitivity and controls the secretion of leptin.\textsuperscript{42} It is possible that the leptin response is different in diverse types of carbohydrates. Also, the effect of high carbohydrate intake on leptin concentration may implicate in obese subjects.\textsuperscript{8} Sex and body fat are two most important factors in concentration of leptin that are supported by evidence.\textsuperscript{43} Weight loss and starvation also can
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decrease circulating of leptin. According to evidence, SFA enhance the risk of obesity that may be mediated through a change in concentration of the hormone. Experimental studies showed that high-fat diets may elevate the leptin concentration. It seems that a diet rich in MUFA and PUFA decrease the concentration of the hormone especially in women compared to SFA. Dietary patterns rich in MUFA and PUFA usually characterized by high amount of fiber sources as well as low glycemic index of carbohydrate that lead to the lower concentration of leptin. Given the important role of estrogen on expression of leptin, it is possible that the type of fatty acids has more effects on women than men.

To the best of our knowledge, fewer evidence is available regarding the impact of high protein diet on leptin concentration. It seems that higher protein intake increases satiety and enhances the leptin concentrations in CNS as well as elevates leptin sensitivity which tends to be weight maintenance. However, different protein sources were found to have diverse effects on health status.

Based on studies, individuals who consumed more energy from protein were found to have greater satiety. Increase in dietary protein intakes promotes an inverse energy balance and body fat loss. On the other hand, protein intake tends to increase energy expenditure that may be related to leptin action.

**Conclusion**

Findings from several studies suggest that a diet display an important role on change the concentration of leptin.

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**Conflict of Interests**

Authors have no conflict of interests.

**References**

1. Kratz M, von EA, Fobker M, Buyken A, Posny N, Schulte H, et al. The impact of dietary fat composition on serum leptin concentrations in healthy nonobese men and women. J Clin Endocrinol Metab 2002; 87(11): 5008-14.

2. Pellemounter MA, Cullen MJ, Baker MB, Hecht R, Winters D, Boone T, et al. Effects of the obese gene product on body weight regulation in ob/ob mice. Science 1995; 269(5223): 540-3.

3. Lonnqvist F, Arner P, Nordfors L, Schalling M. Overexpression of the obese (ob) gene in adipose tissue of human obese subjects. Nat Med 1995; 1(9): 950-3.

4. Otto-Buczkowska E, Chobot A. Role of ghrelin and leptin in the regulation of carbohydrate metabolism. Part II. Leptin. Postepy Hig Med Dosw (Online) 2012; 66: 799-803.

5. Weigle DS, Cummings DE, Newby PD, Breen PA, Frayo RS, Mathys CC, et al. Roles of leptin and ghrelin in the loss of body weight caused by a low fat, high carbohydrate diet. J Clin Endocrinol Metab 2003; 88(4): 1577-86.

6. Herrmann TS, Bean ML, Black TM, Wang P, Coleman RA. High glycemic index carbohydrate diet alters the diurnal rhythm of leptin but not insulin concentrations. Exp Biol Med (Maywood) 2001; 226(11): 1037-44.

7. Kalaitzakis E, Bosaes I, Ohman L, Bjornsson E. Altered postprandial glucose, insulin, leptin, and ghrelin in liver cirrhosis: correlations with energy intake and resting energy expenditure. Am J Clin Nutr 2007; 85(3): 808-15.

8. Martin LJ, Siliart B, Lutz TA, Biourge V, Nguyen P, Dumon HJ. Postprandial response of plasma insulin, amylase and acylated ghrelin to various test meals in lean and obese cats. Br J Nutr 2010; 103(11): 1610-9.

9. Maffei M, Halaas L, Ravussin E, Pratley RE, Lee GH, Zhang Y, et al. Leptin levels in human and rodent: measurement of plasma leptin and ob RNA in obese and weight-reduced subjects. Nat Med 1995; 1(11): 1155-61.

10. Caro JF, Sinha MK, Kolaczynski JW, Zhang PL, Considine RV. Leptin: the tale of an obesity gene. Diabetes 1996; 45(11): 1455-62.

11. Iritani N. Nutritional and insulin regulation of leptin gene expression. Curr Opin Clin Nutr Metab Care 2000; 3(4): 275-9.

12. Farooqi IS, Wangensteen T, Collins S, Kimber W, Matarese G, Keogh JM, et al. Clinical and molecular genetic spectrum of congenital deficiency of the leptin receptor. N Engl J Med 2007; 356(3): 237-47.

13. Sullivan TM, Micke GC, Perkins N, Martin GB, Wallace CR, Gatford KL, et al. Dietary protein during gestation affects maternal insulin-like growth factor, insulin-like growth factor binding protein, leptin concentrations, and fetal growth in heifers. J Anim Sci 2009; 87(10): 3304-16.

14. Hynes GR, Heshka J, Chadee K, Jones PJ. Effects of dietary fat type and energy restriction on adipose tissue fatty acid composition and leptin production in rats. J Lipid Res 2003; 44(5): 893-901.

15. Weigle DS, Breen PA, Mathys CC, Callahan HS, Meeuws KE, Burden VR, et al. A high-protein diet induces sustained reductions in appetite, ad libitum caloric intake, and body weight despite compensatory regulation of circulating ghrelin.
changes in diurnal plasma leptin and ghrelin concentrations. Am J Clin Nutr 2005; 82(1): 41-8.

16. Kong A, Neuhouser ML, Xiao L, Ulrich CM, McTiernan A, Foster-Schubert KE. Higher habitual intake of dietary fat and carbohydrates are associated with lower leptin and higher ghrelin concentrations in overweight and obese postmenopausal women with elevated insulin levels. Nutr Res 2009; 29(11): 768-76.

17. Lopes IM, Forga L, Martinez JA. Effects of leptin resistance on acute fuel metabolism after a high carbohydrate load in lean and overweight young men. J Am Coll Nutr 2001; 20(6): 643-8

18. Al-Delaimy WK, Natarajan L, Rock CL, Sun S, Flatt JP, Pierce JP. Insulin-like growth factor I, insulin-like growth factor I binding protein 1, insulin, glucose, and leptin serum levels are not influenced by a reduced-fat, high-fiber diet intervention. Cancer Epidemiol Biomarkers Prev 2006; 15(6): 1238-9.

19. Rojo-Martinez G, Soriguer FJ, Gonzalez-Romero S, Timahones F, Moreno F, de Adana SR, et al. Serum leptin and habitual fatty acid dietary intake in patients with type 1 diabetes mellitus. Eur J Endocrinol 2000; 142(3): 263-8.

20. Cha MC, Jones PJ. Dietary fat type and energy restriction interactively influence plasma leptin concentration in rats. J Lipid Res 1998; 39(8): 1655-60.

21. Scarpese PJ, Zhang Y. Leptin resistance: a predisposing factor for diet-induced obesity. Am J Physiol Regul Integr Comp Physiol 2009; 296(3): R493-R500.

22. Morrison CD, Huypens P, Stewart LW, Gettys TW. Implications of crosstalk between leptin and insulin signaling during the development of diet-induced obesity. Biochim Biophys Acta 2009; 1792(5): 409-16.

23. Reseland JE, Haugen F, Hollung K, Solvoll K, Halvorsen B, Brude IR, et al. Reduction of leptin gene expression by dietary polyunsFA. J Lipid Res 2001; 42(5): 743-50.

24. Piek B, von EA, Ulrich CM, McTiernan A, Foster-Schubert KE. Higher habitual intake of dietary fat and carbohydrates are associated with lower leptin and higher ghrelin concentrations in overweight and obese postmenopausal women with elevated insulin levels. Nutr Res 2009; 29(11): 768-76.

25. Heshka JT, Jones PJ. A role for dietary fat in leptin receptor, OB-Rb, function. Life Sci 2001; 69(9): 987-1003.

26. Higuchi T, Shira N, Saito M, Suzuki H, Kagawa Y. Levels of plasma insulin, leptin and adiponectin, and activities of key enzymes in carbohydrate metabolism in skeletal muscle and liver in fasted ICR mice fed dietary n-3 polyunsaturated fatty acids. J Nutr Biochem 2008; 19(9): 577-86.

27. Vester BM, Belsito KR, Swanson KS. Serum metabolites, ghrelin and leptin are modified by age and/or diet in weanling kittens fed either a high- or moderate-protein diet. Anim Sci J 2012; 83(5): 426-33.

28. Havel PJ, Townsend R, Chaump L, Teff K. High-fat meals reduce 24-h circulating leptin concentrations in women. Diabetes 1999; 48(2): 334-41.

29. Niswender KD, Magnuson MA. Obesity and the beta cell: lessons from leptin. J Clin Invest 2007; 117(10): 2753-6.

30. Yildiz S, Blache D, Celebi F, Kaya I, Saatci M, Cenesiz M, et al. Effects of short-term high carbohydrate or fat intakes on leptin, growth hormone and luteinizing hormone secretions in prepubertal fat-tailed Tuj lambs. Reprod Domest Anim 2003; 38(3): 182-6.

31. Roberts CK, Berger JJ, Barnard RJ. Long-term effects of diet on leptin, energy intake, and activity in a model of diet-induced obesity. J Appl Physiol (1985) 2002; 93(3): 887-93.

32. Kozlowska L, Rosolowska-Huszc D, Rydzewski A. Low protein diet causes a decrease in serum concentrations of leptin and tumour necrosis factor-alpha in patients with conservatively treated chronic renal failure. Nephrology (Carlton) 2004; 9(5): 319-24.

33. Du F, Higginbotham DA, White BD. Food intake, energy balance and serum leptin concentrations in rats fed low-protein diets. J Nutr 2000; 130(3): 514-21.

34. Nakamura Y, Okuda N, Murakami Y, Miura K, Kita Y, et al. Serum leptin and total dietary energy intake: the INTERLIPID Study. Eur J Nutr 2013; 52(6): 1641-8.

35. Mars M, de Graaf C, de Groot CP, van Rossum CT, Kok FJ. Fasting leptin and appetite responses induced by a 4-day 65%-energy-restricted diet. Int J Obes (Lond) 2006; 30(1): 122-8.

36. Kolaczynski JW, Ohannesian JP, Considine RV, Marco CC, Caro JF. Response of leptin to short-term and prolonged overfeeding in humans. J Clin Endocrinol Metab 1996; 81(11): 4162-5.

37. Marino JS, Xu Y, Hill JW. Central insulin and leptin-mediated autonomic control of glucose homeostasis. Trends Endocrinol Metab 2011; 22(7): 275-85.

38. Vela-Huerta MM, San Vicente-Santoscoy EU, Guizar-Mendoza JM, Amador-Licona N, Aldana-Valenzuela C, Hermandez J. Leptin, insulin, and glucose serum levels in large-for-gestational-age infants of diabetic and non-diabetic mothers. J Pediatr Endocrinol Metab 2008; 21(1): 17-22.

39. AzadibaKht L, Fard NR, Karimi M, Baghaei MH, Surkan PJ, Rahimi M, et al. Effects of the Dietary Approaches to Stop Hypertension (DASH) eating plan on cardiovascular risks among type 2 diabetic
patients: a randomized crossover clinical trial. Diabetes Care 2011; 34(1): 55-7.

40. Azadbakht L, Surkan PJ, Esmaillzadeh A, Willett WC. The Dietary Approaches to Stop Hypertension eating plan affects C-reactive protein, coagulation abnormalities, and hepatic function tests among type 2 diabetic patients. J Nutr 2011; 141(6): 1083-8.

41. Azadbakht L, Miriran P, Esmaillzadeh A, Azizi F. Dairy consumption is inversely associated with the prevalence of the metabolic syndrome in Tehranian adults. Am J Clin Nutr 2005; 82(3): 523-30.

42. Jensen MK, Koh-Banerjee P, Franz M, Sampson L, Gronbaek M, Rimm EB. Whole grains, bran, and germ in relation to homocysteine and markers of glycemic control, lipids, and inflammation I. Am J Clin Nutr 2006; 83(2): 275-83.

43. Considine RV, Sinha MK, Heiman ML, Kriauciunas A, Stephens TW, Nyce MR, et al. Serum immunoreactive-leptin concentrations in normal-weight and obese humans. N Engl J Med 1996; 334(5): 292-5.

44. Surwit RS, Petro AE, Parekh P, Collins S. Low plasma leptin in response to dietary fat in diabetes- and obesity-prone mice. Diabetes 1997; 46(9): 1516-20.

45. Jenkins AB, Markovic TP, Fleury A, Campbell LV. Carbohydrate intake and short-term regulation of leptin in humans. Diabetologia 1997; 40(3): 348-51.

46. Pawlak DB, Bryson JM, Denyer GS, Brand-Miller JC. High glycemic index starch promotes hypersecretion of insulin and higher body fat in rats without affecting insulin sensitivity. J Nutr 2001; 131(1): 99-104.

47. Azadbakht L, Izadi V, Surkan PJ, Esmaillzadeh A. Effect of a High Protein Weight Loss Diet on Weight, High-Sensitivity C-Reactive Protein, and Cardiovascular Risk among Overweight and Obese Women: A Parallel Clinical Trial. Int J Endocrinol 2013: 2013: 971724.

48. Krebs NF, Gao D, Gralla J, Collins JS, Johnson SL. Efficacy and safety of a high protein, low carbohydrate diet for weight loss in severely obese adolescents. J Pediatr 2010; 157(2): 252-8.

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