Prediabetes: A Prevalent and Treatable, but Often Unrecognized, Clinical Condition

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TYPE 2 DIABETES MELLITUS AFFECTS MORE THAN 8% of the United States population.[1] The onset of type 2 diabetes is gradual, with most individuals progressing through a state of prediabetes, which is defined as one or more of the following: impaired fasting glucose (IFG, plasma glucose of 100 to 125 mg/dL [5.6 to 6.9 mmol/L]), impaired glucose tolerance (IGT, plasma glucose of 140 to 199 mg/dL [7.8 to 11.0 mmol/L] 2 hours after an oral load of 75 g dextrose), or hemoglobin A1c 5.7% to 6.4%.[2] According to a study of a nationally representative sample (n=1,547), an estimated 35% of the United States population has prediabetes: 19% have IFG only, 5% have IGT only, and 10% have both IFG and IGT.[3] Although individuals can spend years in a prediabetes stage, an expert American Diabetes Association (ADA) panel estimated that up to 70% of individuals with prediabetes will eventually progress to type 2 diabetes.[4] However, not all individuals with prediabetes progress at the same rate. A meta-analysis of prospective cohort studies showed that the annual incidence of diabetes in people with IGT, IFG, or both was 6.1%, 7.0%, and 14.0%, respectively.[5]

The diagnosis of prediabetes presents health care providers with an opportunity to identify patients at increased risk for type 2 diabetes and to implement interventions that can delay or prevent type 2 diabetes and its complications.[4] Unfortunately, this opportunity is often unrecognized; an analysis of a nationally representative sample of patients with prediabetes (n=584) concluded that only 31.7% had been counseled about exercise, 33.4% about diet, and 25.9% about both exercise and diet by a physician or other health professional.[3] Possible reasons for not counseling patients include lack of reimbursement, lack of resources, lack of time, and lack of skill.[6,7] However, individuals who have been counseled by their health care provider to adopt a healthy lifestyle reported greater adherence to weight control and diet modification and had lower low-density lipoprotein (LDL) cholesterol, lower body mass index (BMI), and higher high-density lipoprotein (HDL) cholesterol.[8]

Still, it is unclear whether counseling sessions by a primary care provider in the outpatient setting are correlated with improvements in fasting plasma glucose in patients with prediabetes compared with similar patients who have not been counseled. Although some evidence suggests that lifestyle counseling may be associated with self-reported changes in lifestyle behavior in overweight and obese adults with prediabetes and diabetes,[9] other data suggest that lifestyle intervention programs that have been implemented in the outpatient health care setting have had an insignificant impact on fasting plasma glucose.[6] Nevertheless, according to ADA guidelines there is clear evidence to support providing medical nutrition therapy to patients with prediabetes.[10] Given the high prevalence of prediabetes, it is important to understand the basic underlying pathophysiology and how lifestyle interventions can be implemented in the clinical setting to reduce a patient's risk for progressing to type 2 diabetes.

PATHOPHYSIOLOGY OF PREDIABETES

The same pathophysiologic defects lie at the heart of both IFG and IGT: beta cell dysfunction and insulin resistance. In both IFG and IGT, glucose-stimulated insulin secretion is impaired.[11] There is also fasting hyperinsulinemia due to a compensatory pancreatic beta cell response to fasting hyperglycemia.[12] However, there are differences between IFG and IGT. IFG is associated with a more severe hepatic insulin resistance than IGT.[12,13] IGT is associated with insulin resistance in skeletal muscle whereas IFG is not.[11] Nevertheless, the clinical significance of these pathophysiologic differences has not been established.[14]

It is possible that diet may affect individuals with IGT and IFG differently. An investigation of individuals (n=5,824; age 30 to 60 years) in the Inter99 study, a randomized intervention study of participants randomly sampled from a specific region of Denmark, found that individuals with diets that routinely included pâté, mayonnaise salads, red meat, potatoes, lard, and/or butter developed worsening oral glucose tolerance, but no change in fasting plasma glucose concentrations was observed over a 5-year period.[15] Thus, patients with IGT may respond better to dietary intervention than do those with IFG.[16] Nevertheless, although there are distinct differences in the pathophysiology of IFG and IGT, no prospective study has looked at whether dietary interventions have different impacts on oral glucose tolerance vs fasting plasma glucose concentrations.

- Body mass index ≥25
- Physical inactivity
- First-degree relative with type 2 diabetes mellitus
- High-risk race/ethnicity (eg, African America, Latino, Native American, Asian American, Pacific Islander)
- Women who delivered a baby weighing >9 lb
- Women who were diagnosed with gestational diabetes
- Hypertension (≥140/90 mm Hg or on therapy for hypertension)
- High-density lipoprotein cholesterol <35 mg/dL (0.90 mmol/L) and/or triglycerides >250 mg/dL (2.82 mmol/L)
- Women with polycystic ovarian syndrome
- Hemoglobin A1c ≥5.7%, impaired oral glucose tolerance, or impaired fasting glucose on previous testing
- Other clinical conditions associated with insulin resistance (eg, severe obesity, acanthosis nigricans)
- History of cardiovascular disease
- Absence of above criteria but age 45 years or older

Figure. Risk factors for prediabetes, according to the American Diabetes Association.

Diet composition can affect insulin sensitivity and beta cell function. Diet-induced weight loss improves insulin sensitivity as well as beta-cell function.[17] Both energy-restrictive low-fat and low-carbohydrate diets improve hepatic insulin sensitivity and decrease hepatic glucose production with as little as a 2% weight loss, and improve skeletal muscle insulin sensitivity after a 7% weight loss.[18] A diet rich in saturated fatty acids (14%, 17%, and 6% total energy from monounsaturated, saturated, and polyunsaturated fatty acids, respectively) impairs insulin sensitivity, whereas a diet rich in monounsaturated fatty acids (23%, 8%, and 6% total energy from monounsaturated, saturated, and polyunsaturated fatty acids, respectively) does not seem to alter insulin sensitivity.[19] In addition, substitution of polyunsaturated fats for saturated fats,[20] consumption of 31.2 g of insoluble dietary fiber daily,[21] and substitution of 6 to 10 daily servings of refined grains with whole grains[22] may improve peripheral insulin sensitivity. Low-glycemic-index foods may reduce the risk of type 2 diabetes,[23,24] although some studies report no reduction in type 2 diabetes risk.[25,26] However, the relationship between consumption of low-glycemic-index foods and plasma glucose concentration is complex and is altered by the protein and fat composition of a meal, preparation and processing of the food items, prior food intake, fasting or preprandial plasma glucose levels, and degree of insulin resistance.[27]

IDENTIFYING RISK FACTORS FOR PREDIABETES

The risk factors for prediabetes are the same as those for type 2 diabetes. The ADA recommends testing asymptomatic adults for type 2 diabetes if they meet any of the criteria (Figure) that indicate increased risk for type 2 diabetes.[10]

The following case presentation illustrates the importance of recognizing prediabetes and identifies lifestyle modifications that can be used to treat prediabetes in clinical settings. The assessment, intervention, monitoring, and evaluation were done in an outpatient clinic setting by a medical student/research assistant trained to conduct dietary assessments. The case study was conducted and prepared in accordance with the Health Insurance Portability and Accountability Act.

Patient Profile

JS is a 51-year-old, overweight (BMI=28.9), nonsmoking white man treated for hyperlipidemia and hypertension for the past 11 years. His clinical data are reported in the Table. On an annual outpatient visit and physical exam in January of 2011, his systolic blood pressure was 140 mm Hg despite being treated with lisinopril (20 mg/day). His labs were noteworthy for an impaired fasting serum glucose of 112 mg/dL (6.22 mmol/L) and an LDL cholesterol of 98 mg/dL (2.54 mmol/L), which was being controlled by simvastatin (20 mg/day). JS reported that his job required frequent travel and overnight stays at hotels and that he consequently often ate meals prepared outside of the house. He felt that his poor diet and exercise habits had contributed to his now elevated fasting glucose concentration, his overweight status, and his chronic hypertension and hyperlipidemia. In July 2011, the patient reported a desire to make lifestyle changes.

Assessment

A dietary assessment and 24-hour dietary recall was done for JS on July 19, 2011; these data along with the National Heart, Lung, and Blood Institute's National Cholesterol Education Program (NCEP) recommendations are reported in the Table. JS's intake of fat, saturated fat, dietary cholesterol, sodium, and protein exceeded NCEP recommendations for hyperlipidemic adults by 1.6%, 1.5%, 264%, 154%, and 10%, respectively.[28] His intake of fiber was adequate per NCEP recommendations but not ADA recommendations,[10] and his carbohydrate intake was less than NCEP recommendations.

JS reported that his physical activity (approximately 15 min/day) consisted of walking from his car to his destination. Based on JS's height, weight, age, and sedentary physical activity level, his total estimated energy requirement was 2,273

Table. Pre-interventional and post-interventional laboratory and 24-hour dietary recall results[a] from clinical encounters with a 51-year-old patient with prediabetes, hyperlipidemia, and hypertension

Laboratory Results

	Pre-Intervention			Post-Intervention
Value (reference range)	July 21, 2009	December 16, 2009	January 10, 2011	December 15, 2011
Fasting plasma glucose, mg/dL[b] (<100 mg/dL)	95	[c]	112	100
Total cholesterol, mg/dL[d] (<200 mg/dL)	204	[c]	182	166
LDL[e] cholesterol, mg/dL[d] (<100 mg/dL)	128	[c]	98	80
HDL[f] cholesterol, mg/dL[d] (>39 mg/dL)	49	[c]	56	54
Triglycerides, mg/dL[g] (<150 mg/dL)	135	[c]	142	160
Systolic blood pressure, mm Hg (<120 mm Hg)	144	137	140	146
Diastolic blood pressure, mm Hg (<80 mm Hg)	94	84	80	88
Weight, kg	93.0	92.1	93.9	90.7
BMI[h] (18.5-25)	28.6	28.3	28.9	27.9

24-Hour Dietary Recall Results

Nutrient	Amount reported	NCEP recommendations[2]	Nutrition diagnostic label number[51]	Nutrition intervention recommendations
Energy, kcal	2,182		NI-1.5[i]	1,773
Fat, kcal	888			614
Total fat	100 g (36.6%)	25%-35%[j]	NI-51.2	81 g (36.5%)
Saturated fat	32 g (8.5%)	<7%	NI-51.3	15 g (7.0%)
Trans fat, g	3	[k]		0
Cholesterol, g	727	<200		200
Sodium, mg	6,090	2,400	NI-55.2	2,400
Total carbohydrate	192 g (38.4%)	50%-60%		170 g (38.4%)
Dietary fiber, g	22	20-30	NI-5.8.5[l]	24
Sugars, g	133			
Protein	136 g (25%)	15%		110 g (24.8%)

[a]24-hour dietary recall results are compared with National Cholesterol Education Program (NCEP) and individualized dietary recommendations. Nutrition diagnostic label numbers are presented for some nutrients based on discrepancies between reported nutrient intakes and NCEP recommendations.
[b]To convert mg/dL glucose to mmol/L, multiply mg/dL by 0.0555. To convert mmol/L glucose to mg/dL, multiply mmol/L by 18.0. Glucose of 108 mg/dL=6.0 mmol/L.
[c]Values not available.
[d]To convert mg/dL cholesterol to mmol/L, multiply mg/dL by 0.0259. To convert mmol/L cholesterol to mg/dL, multiply mmol/L by 38.7. Cholesterol of 193 mg/dL=5.00 mmol/L.
[e]LDL=low-density lipoprotein.
[f]HDL=high-density lipoprotein.
[g]To convert mg/dL triglyceride to mmol/L, multiply mg/dL by 0.0113. To convert mmol/L triglyceride to mg/dL, multiply mmol/L by 88.6. Triglyceride of 159 mg/dL=1.80 mmol/L.
[h]BMI=body mass index.
[i]As evidenced by observed weight gain from December 2009 to January 2011.
[j]Percentage of total energy.
[k]NCEP guidelines indicate that *trans* fats should be kept low but do not include a quantitative recommendation.
[l]Reported fiber intake meets NCEP but not American Diabetes Association fiber intake recommendation of 14 g of fiber per 1,000 kcal for type 2 diabetes mellitus prevention.[10]

kcal/day, per the Mifflin-St Jeor equation[29] and a physical activity level of 1.25.[30]

Diagnosis

Based on the assessment, and considering the nutrition diagnostic labels (included in parentheses) listed for specific nutrient discrepancies between reported intakes compared with NCEP recommendations, the following Nutrition Diagnostic Statements were developed:

- Overweight (NC-3.3) related to excessive energy intake and physical inactivity as evidenced by a BMI more than 25.
- Undesirable food choices (NB-1.7) related to a food and knowledge deficit as evidenced by excessive intake of *trans* fat, saturated fat, dietary cholesterol, sodium, and protein; elevated fasting glucose concentration; observed weight gain; BMI; hypertension; and hyperlipidemia.
- Physical inactivity (NB-2.1) related to perceived lack of time for exercise as evidenced by client history.

Intervention

The intervention was done on July 22, 2011. JS was advised to reduce his energy consumption by 500 kcal per day, reduce sodium intake, and increase consumption of fiber-rich foods (see Table; comprehensive nutrition education, E-2). JS reported a preference for fat-rich foods over foods higher in carbohydrates, so he was advised to make modest reductions of both macronutrients to reduce energy intake. JS was advised to substitute water for sugar-sweetened beverages. To increase fiber intake, he was advised to choose whole fruits over the fruit juices that he had been consuming. JS was also advised to reduce his saturated fat consumption by choosing leaner meats and low-fat cheeses and substituting oils for butter. In addition, JS was advised to minimize consumption of foods that contain *trans* fats. With regard to problem-solving strategies, it was suggested that JS prepare breakfasts, snacks, and lunches for his trips (nutrition counseling, C-1), which would be lower in energy, saturated fat, and sodium and higher in fiber than meals that he would otherwise consume while traveling. Another strategy to make better food choices was to dine at restaurants that report nutritional information. JS was also educated about portion sizes and making healthier food choices in scenarios when nutritional information was not reported. In addition, JS was advised to engage in 150 minutes of moderate intensity physical activity of his choice each week. He expressed interest in adding walking and resistance training to his current physical activity regimen. He was encouraged to pursue these activities but advised to seek professional instruction before pursuing a resistance-training program. JS was counseled that the recommended changes in diet and physical activity should become a permanent part of his lifestyle.

Monitoring and Evaluation

According to Academy of Nutrition and Dietetics *Nutrition Care Manual* guidelines, lifestyle interventions can be monitored by all of the following: client food and physical activity logs, anthropometric measurements, biochemical data, client questionnaires, and/or telephone or mail communications with the client.[31] The ADA recommends at least annual monitoring of individuals with prediabetes for the development of diabetes, which can be done by measuring fasting plasma glucose, the 2-hour value in the 75-g oral glucose tolerance test, or hemoglobin A1c.[10] Changes in body weight and biochemical data were used to monitor JS; however, monitoring would have been more comprehensive if it had included a postintervention 24-hour dietary recall.

The postintervention data are reported in the Table. JS's body weight decreased 3.2 kg (−3.4%). This represents an approximate 51% reduction in type 2 diabetes risk based on a study of patients with prediabetes (n=1,079), which determined that for every kilogram of weight lost, there was a 16% reduction in type 2 diabetes risk, adjusted for both diet and activity.[32] JS's fasting plasma glucose decreased from 112 mg/dL (6.216 mmol/L) to 100 mg/dL (5.550 mmol/L) over the 11-month period, which is clinically significant based on results of an investigation of individuals with prediabetes (n=5,452) that reported a threefold greater progression to type 2 diabetes over a 2- to 11-year period among those with a fasting glucose concentration ranging 110 to 125 mg/dL (6.105 to 6.938 mmol/L) compared with those in the 100 to 109 mg/dL (5.550 to 6.045 mmol/L) range.[33] There was an approximate 18% reduction in LDL cholesterol, from 98 mg/dL (2.538 mmol/L) to 80 mg/dL (2.072 mmol/L). However, it is uncertain whether reductions of LDL cholesterol within the NCEP's optimal goal range of less than 100 mg/dL (<2.590 mmol/L) result in an additional reduction in cardiovascular disease risk in individuals like JS who are at moderate risk for and have no history of coronary heart disease.[28] However, there was an increase in serum triglycerides from 142 mg/dL (1.605 mmol/L) to 160 mg/dL (1.808 mmol/L) that was significant because it brought JS's serum triglycerides into NCEP's borderline-high triglyceride category (150 to 199 mg/dL [1.695 to 2.249 mmol/L]).[28] There was relatively little change in blood pressure and HDL cholesterol. A telephone follow-up at 1-year post-intervention (July 20, 2012) indicated that JS was still adhering to dietary recommendations, was still participating in resistance training and aerobic exercise 3 days per week, was satisfied with his progress, and did not currently desire additional assistance.

DISCUSSION

Lifestyle intervention is recommended for individuals with prediabetes to prevent or delay the onset of type 2 diabetes, postpone pharmacologic treatment, preserve beta cell function, and reduce the likelihood of microvascular and cardiovascular complications.[4,34,35] The Diabetes Prevention Program demonstrated that the dominant predictor of reduced type 2 diabetes incidence was weight loss.[32] Thus, when developing an intervention for a patient with prediabetes, comprehensive lifestyle change should be recommended to most effectively achieve weight loss and subsequent reduction in type 2 diabetes risk.

A meta-analysis of 10 prospective cohort studies including 301,221 participants and 9,367 incident cases showed that moderate-intensity activity for at least 150 minutes per week reduces the risk of developing type 2 diabetes in individuals with IGT or IFG.[36] Consistent with these findings, the ADA recommends that individuals with prediabetes engage in 150 minutes of moderate-intensity physical activity per week.[10]

Regular physical activity may also reduce blood pressure,[37] which is relevant to this clinical case. In addition, the ADA recommends that individuals with type 2 diabetes engage in resistance training three times per week.[10] JS was encouraged to engage in resistance training based on these recommendations, which are supported by research that suggests that resistance training may improve insulin sensitivity and prevent the onset of type 2 diabetes with advancing age.[38]

Individuals at high risk for type 2 diabetes and individuals with type 2 diabetes should aim to reduce intake of energy, saturated fat, and *trans* fat.[10] These recommendations are consistent with the NCEP recommendations (see Table). Accordingly, recommendations for JS included reduction of energy intake to 500 kcal less than his daily estimated energy requirement of 2,273 kcal, reduction of saturated fat to less than 7% of total energy, and minimization of energy from *trans* fat. The reduction in saturated fat and *trans* fat is consistent with evidence that reducing saturated fat intake decreases LDL cholesterol and minimizing *trans* fat intake increases HDL cholesterol and decreases LDL cholesterol,[39] which is important for individuals who require statins to control LDL cholesterol levels. Because of this patient's hypertension, a reduction in sodium intake to 2.4 g per day was recommended based on guidelines from the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure.[40] Elimination of sugar-sweetened beverages is consistent with United States Dietary Guidelines[41] and ADA guidelines[10] and is supported by a meta-analysis of several studies that associate sugar-sweetened beverage consumption with an increased risk for metabolic syndrome and type 2 diabetes.[42] Finally, although it was recommended that JS reduce his total energy intake, the relative proportions of fat and carbohydrates were kept at a level that was preferred by JS because the optimal macronutrient distribution of weight-loss diets has not been established.[10]

The clinical intervention accomplished the primary goal of reducing JS's fasting blood glucose, which may be attributable to weight loss, dietary changes, increased physical activity, and/or resistance training. The intervention also reduced JS's LDL cholesterol, which is possibly attributable to weight loss,[43] resistance training,[44] reduction in saturated fat consumption,[39,45] and/or reduction in *trans* fat consumption.[39,46] It is unclear why the triglyceride concentration increased. This is contrary to evidence that suggests a reduction in body weight,[43,47] a reduction in carbohydrates,[48] aerobic exercise,[49,50] and resistance training[44] may reduce blood triglycerides.

The patient in this study presented with IFG and an unknown oral glucose tolerance status. Although there is evidence suggesting a difference in the pathophysiology of IFG vs IGT, clinical guidelines do not suggest testing for both fasting plasma glucose and oral glucose tolerance, and the IFG vs IGT status of a patient does not currently alter treatment. Therefore, additional research is warranted to determine whether certain dietary strategies are more effective in treating patients IFG only vs patients with both IFG and IGT.

References

1. Centers for Disease Control and Prevention. National diabetes fact sheet: National estimates and general information on diabetes and prediabetes in the United States, 2011. http://www.cdc.gov/diabetes/pubs/pdf/ndfs_2011.pdf. Accessed June 30, 2011.
2. Diagnosis and classification of diabetes mellitus. *Diabetes Care*. 2012; 35(suppl 1):S64-S71.
3. Karve A, Hayward RA. Prevalence, diagnosis, and treatment of impaired fasting glucose and impaired glucose tolerance in nondiabetic US adults. *Diabetes Care*. 2010;33(11):2355-2359.
4. Nathan DM, Davidson MB, DeFronzo RA, et al. Impaired fasting glucose and impaired glucose tolerance: Implications for care. *Diabetes Care*. 2007;30(3):753-759.
5. Gerstein HC, Santaguida P, Raina P, et al. Annual incidence and relative risk of diabetes in people with various categories of dysglycemia: A systematic overview and meta-analysis of prospective studies. *Diabetes Res Clin Pract*. 2007;78(3):305-312.
6. Cardona-Morrell M, Rychetnik L, Morrell SL, Espinel PT, Bauman A. Reduction of diabetes risk in routine clinical practice: are physical activity and nutrition interventions feasible and are the outcomes from reference trials replicable? A systematic review and meta-analysis. *BMC Public Health*. 2010;10:653.
7. Ben-Arye E, Lear A, Hermoni D, Margalit RS. Promoting lifestyle self-awareness among the medical team by the use of an integrated teaching approach: A primary care experience. *J Altern Complement Med*. 2007;13(4):461-469.
8. Yang K, Lee YS, Chasens ER. Outcomes of health care providers' recommendations for healthy lifestyle among US adults with prediabetes. *Metab Syndr Relat Disord*. 2011;9(3):231-237.
9. Dorsey R, Songer T. Lifestyle behaviors and physician advice for change among overweight and obese adults with prediabetes and diabetes in the United States, 2006. *Prev Chronic Dis*. 2011;8(6):A132.
10. Standards of medical care in diabetes–2012. *Diabetes Care*. 2012; 35(suppl 1):S11-S63.
11. Abdul-Ghani MA, DeFronzo RA. Pathophysiology of prediabetes. *Curr Diab Rep*. 2009;9(3):193-199.
12. Abdul-Ghani MA, Tripathy D, DeFronzo RA. Contributions of beta-cell dysfunction and insulin resistance to the pathogenesis of impaired glucose tolerance and impaired fasting glucose. *Diabetes Care*. 2006; 29(5):1130-1139.
13. Jani R, Molina M, Matsuda M, et al. Decreased non-insulin-dependent glucose clearance contributes to the rise in fasting plasma glucose in the nondiabetic range. *Diabetes Care*. 2008;31(2):311-315.
14. Tabak AG, Herder C, Rathmann W, Brunner EJ, Kivimaki M. Prediabetes: A high-risk state for diabetes development. *Lancet*. 2012; 379(9833):2279-2290.
15. Lau C, Toft U, Tetens I, et al. Dietary patterns predict changes in two-hour post-oral glucose tolerance test plasma glucose concentrations in middle-aged adults. *J Nutr*. 2009;139(3):588-593.
16. Faerch K, Borch-Johnsen K, Holst JJ, Vaag A. Pathophysiology and aetiology of impaired fasting glycaemia and impaired glucose tolerance: Does it matter for prevention and treatment of type 2 diabetes? *Diabetologia*. 2009;52(9):1714-1723.
17. Utzschneider KM, Carr DB, Barsness SM, Kahn SE, Schwartz RS. Diet-induced weight loss is associated with an improvement in beta-cell function in older men. *J Clin Endocrinol Metab*. 2004;89(6):2704-2710.
18. Kirk E, Reeds DN, Finck BN, Mayurranjan SM, Patterson BW, Klein S. Dietary fat and carbohydrates differentially alter insulin sensitivity during caloric restriction. *Gastroenterology*. 2009;136(5):1552-1560.
19. Vessby B, Uusitupa M, Hermansen K, et al. Substituting dietary saturated for monounsaturated fat impairs insulin sensitivity in healthy men and women: The KANWU Study. *Diabetologia*. 2001;44(3):312-319.
20. Summers LK, Fielding BA, Bradshaw HA, et al. Substituting dietary saturated fat with polyunsaturated fat changes abdominal fat distribution and improves insulin sensitivity. *Diabetologia*. 2002;45(3): 369-377.
21. Weickert MO, Mohlig M, Schofl C, et al. Cereal fiber improves whole-body insulin sensitivity in overweight and obese women. *Diabetes Care*. 2006;29(4):775-780.
22. Pereira MA, Jacobs DR Jr, Pins JJ, et al. Effect of whole grains on insulin sensitivity in overweight hyperinsulinemic adults. *Am J Clin Nutr*. 2002;75(5):848-855.
23. Barclay AW, Petocz P, McMillan-Price J, et al. Glycemic index, glycemic load, and chronic disease risk—A meta-analysis of observational studies. *Am J Clin Nutr*. 2008;87(3):627-637.

24. Dong JY, Zhang L, Zhang YH, Qin LQ. Dietary glycaemic index and glycaemic load in relation to the risk of type 2 diabetes: A meta-analysis of prospective cohort studies. *Br J Nutr*. 2011;106(11):1649-1654.
25. Meyer KA, Kushi LH, Jacobs DR Jr, Slavin J, Sellers TA, Folsom AR. Carbohydrates, dietary fiber, and incident type 2 diabetes in older women. *Am J Clin Nutr*. Apr 2000;71(4):921-930.
26. Stevens J, Ahn K, Juhaeri, Houston D, Steffan L, Couper D. Dietary fiber intake and glycemic index and incidence of diabetes in African-American and white adults: The ARIC study. *Diabetes Care*. 2002;25(10):1715-1721.
27. Sheard NF, Clark NG, Brand-Miller JC, et al. Dietary carbohydrate (amount and type) in the prevention and management of diabetes: A statement by the American Diabetes Association. *Diabetes Care*. 2004;27(9):2266-2271.
28. Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. *Circulation*. 2002;106(25):3143-3421.
29. Mifflin MD, St Jeor ST, Hill LA, Scott BJ, Daugherty SA, Koh YO. A new predictive equation for resting energy expenditure in healthy individuals. *Am J Clin Nutr*. 1990;51(2):241-247.
30. Otten JJ, Hellwig JP, Meyers LD. *DRI, Dietary Reference Intakes : The Essential Guide to Nutrient Requirements*. Washington, DC: National Academies Press; 2006.
31. Academy of Nutrition and Dietetics. Nutrition Care Manual. www.nutritioncaremanual.org. Accessed July 9, 2012.
32. Hamman RF, Wing RR, Edelstein SL, et al. Effect of weight loss with lifestyle intervention on risk of diabetes. *Diabetes Care*. 2006;29(9):2102-2107.
33. Nichols GA, Hillier TA, Brown JB. Progression from newly acquired impaired fasting glucose to type 2 diabetes. *Diabetes Care*. 2007;30(2):228-233.
34. Knowler WC, Barrett-Connor E, Fowler SE, et al. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med*. 2002;346(6):393-403.
35. Wing RR. Long-term effects of a lifestyle intervention on weight and cardiovascular risk factors in individuals with type 2 diabetes mellitus: Four-year results of the Look AHEAD trial. *Arch Int Med*. 2010;170(17):1566-1575.
36. Jeon CY, Lokken RP, Hu FB, van Dam RM. Physical activity of moderate intensity and risk of type 2 diabetes: A systematic review. *Diabetes Care*. 2007;30(3):744-752.
37. Whelton SP, Chin A, Xin X, He J. Effect of aerobic exercise on blood pressure: A meta-analysis of randomized, controlled trials. *Ann Intern Med*. 2002;136(7):493-503.
38. Flack KD, Davy KP, Hulver MW, Winett RA, Frisard MI, Davy BM. Aging, resistance training, and diabetes prevention. *J Aging Res*. 2010;2011:127315.
39. Van Horn L, McCoin M, Kris-Etherton PM, et al. The evidence for dietary prevention and treatment of cardiovascular disease. *J Am Diet Assoc*. 2008;108(2):287-331.
40. Chobanian AV, Bakris GL, Black HR, et al. Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. *Hypertension*. 2003;42(6):1206-1252.
41. US Department of Agriculture and U.S. Department of Health and Human Services. *Dietary Guidelines for Americans, 2010*. 7th ed. Washington, DC: U.S. Government Printing Office; 2010.
42. Malik VS, Popkin BM, Bray GA, Despres JP, Willett WC, Hu FB. Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: A meta-analysis. *Diabetes Care*. 2010;33(11):2477-2483.
43. Poobalan A, Aucott L, Smith WC, et al. Effects of weight loss in overweight/obese individuals and long-term lipid outcomes–a systematic review. *Obes Rev*. 2004;5(1):43-50.
44. Kelley GA, Kelley KS. Impact of progressive resistance training on lipids and lipoproteins in adults: A meta-analysis of randomized controlled trials. *Prev Med*. 2009;48(1):9-19.
45. Astrup A, Dyerberg J, Elwood P, et al. The role of reducing intakes of saturated fat in the prevention of cardiovascular disease: Where does the evidence stand in 2010? *Am J Clin Nutr*. 2011;93(4):684-688.
46. Mozaffarian D, Aro A, Willett WC. Health effects of *trans*-fatty acids: Experimental and observational evidence. *Eur J Clin Nutr*. 2009;63(Suppl 2):S5-S21.
47. Aucott L, Gray D, Rothnie H, Thapa M, Waweru C. Effects of lifestyle interventions and long-term weight loss on lipid outcomes—A systematic review. *Obes Rev*. 2011;12(5):e412-e425.
48. Hauner H, Bechthold A, Boeing H, et al. Evidence-based guideline of the German Nutrition Society: Carbohydrate intake and prevention of nutrition-related diseases. *Ann Nutr Metab*. 2012;60(Suppl 1):1-58.
49. Chudyk A, Petrella RJ. Effects of exercise on cardiovascular risk factors in type 2 diabetes: A meta-analysis. *Diabetes Care*. 2011;34(5):1228-1237.
50. Kelley GA, Kelley KS, Vu Tran Z. Aerobic exercise, lipids and lipoproteins in overweight and obese adults: A meta-analysis of randomized controlled trials. *Int J Obes (Lond)*. 2005;29(8):881-893.
51. American Dietetic Association. *Nutrition Diagnosis and Intervention: Standardized Language for the Nutrition Care Process*. Chicago, IL: American Dietetic Association; 2007.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

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