A low-fat, whole foods plant-based diet to prevent and accentuate standard treatment for Type 2 Diabetes

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Introduction

Nearly half of all adults in the United States are living with either diabetes or pre-diabetes, and the global prevalence of diabetes has doubled since 1980 (Menke, Casagrande, Geiss, & Cowie, 2015). In 2013, the prevalence of diabetes in adults worldwide was 381.8 million, and is projected to be 591.9 million in 2035 (Guariguata et al., 2014). Diabetes and pre-diabetes cost America $322 billion per year, with 1 in 5 health care dollars being spent on caring for people with diabetes (American Diabetes Association, 2016a). On this day alone, 3,835 Americans will be diagnosed with diabetes, 200 Americans with diabetes will undergo an amputation, 136 will enter end-stage kidney disease treatment, and 1,795 will develop severe retinopathy that can lead to vision loss and blindness (American Diabetes Association, 2016a).

Current treatment guidelines for Type 2 Diabetes (T2D) recommend a target glycated hemoglobin level (HbA_{1c}) of 7% or less for most non-pregnant adults, with the target HbA_{1c} being individualized based on patient (e.g. age) and disease factors (e.g. duration or vascular complications) (American Association of Clinical Endocrinologists, 2016; American Diabetes Association, 2016b). Major randomized controlled trials (RCTs) attempting to prove the benefits of lowering HbA_{1c} with medication combinations and/or multiple daily injections of insulin to achieve intensive glycemic control have been disappointing (ACCORD Study Group, 2016; Duckworth et al., 2011). In a meta-analysis of data from 13 RCTs, intensive glucose lowering treatment (achieving HbA_{1c} of 7% or less) showed no benefit on all-cause mortality or death from cardiovascular comorbidities in adults with T2D; additionally, a 19% increase in all-cause mortality and a 43% increase in death from cardiovascular events were revealed (Boussageon et al., 2011).

The same meta-analysis showed that intensive glucose lowering treatment was associated with a 10% absolute risk reduction of microalbuminuria; however, no significant benefit on microvascular end-points of clinical significance, such as renal failure, neuropathy, retinopathy, or visual deterioration were seen (Boussageon et al., 2011). Furthermore, intensive glucose lowering treatment was associated with a significant twofold increased risk of severe hypoglycemic events (Boussageon et al., 2011). On the other hand, a recent meta-analysis had a different conclusion: data from 58,160 patients in 13 RCTs showed that T2DM patients receiving intensive glucose lowering therapy had a lower incidence of major cardiovascular events and myocardial infarction (MI), with little or no effect on the risk of total mortality, cardiac death, stroke, and congestive heart failure (Fang et al., 2016).

In response to the potential risks and conflicting evidence regarding significant benefits of intensive pharmacological glucose lowering, especially in older adults, along with the demands and expense involved, the American Diabetes Association (ADA) recommends shared decision-making with patients, and a patient-centered approach with more emphasis on cardiovascular risk reduction through healthy habits (Inzucchi et al., 2015; American Diabetes Association, 2016b). These initiatives may help to promote a shift from a culture of primacy of medication for prevention and treatment of T2D to one that boldly promotes “intensive” therapeutic lifestyle and dietary changes as an integral and early component of therapy. Once individuals have progressed to diabetes, they will most likely require medication to lessen their HbA_{1c} to a reasonable goal. However, when individuals are still in the pre-diabetic stage (HbA_{1c} 5.7-6.4%), health care providers can seize the opportunity to target interventions, such as therapeutic lifestyle and dietary changes, to prevent the progression of the disease . In addition to reducing the risk for diabetes, intensive dietary and lifestyle changes may reduce cardiovascular risk factors by improving blood pressure and lipid control and reducing weight, as advocated by the 2016 Standards of Medical Care in Diabetes (American Diabetes Association, 2016b).

Medical nutrition therapy and current standards for treatment of type 2 diabetes

Medical nutrition therapy (MNT) is an integral part of the foundation of diabetes treatment in the 2016 Standards of Medical Care in Diabetes; unfortunately, it is also noted that "for many individuals with diabetes, the most challenging part of the treatment plan is determining what to eat" (American Diabetes Association, 2016b, p.25). It is the position of the ADA that there is not a one-size-fits-all eating pattern for individuals with diabetes, and recommendations are equally vague about how pre-diabetic individuals should eat to prevent the disease (American Diabetes Association, 2016b). While the ADA recognizes the integral role of MNT in overall diabetes management and recommends each person with diabetes be actively engaged in self-management, education, and treatment planning with his or her health care team, including developing an individualized eating plan, health care providers are typically underprepared to be able to provide nutrition counseling (American Diabetes Association, 2016b). Only 14% of resident physicians believe they are adequately trained to provide nutrition counseling; yet, a survey of the public conducted by the ADA showed that 61% of individuals consider doctors to be "very credible" sources of nutrition information (Devries et al., 2014). Medical schools generally include less than 20 credit hours of nutrition education, and most occurs in the early years of medical school with little apparent connection to human diets and common diseases (Devries et al., 2014). Health care providers may feel inadequate addressing diet recommendations due to a lack of education, and with vague recommendations in major guidelines such as the Standard of Medical Care in Diabetes, there may be heavier reliance upon medication therapy for the disease.

The current standard of care for diabetes recommends metformin as first line therapy (American Diabetes Association, 2016b). After three months of monotherapy where goal HbA_{1c} is not reached, the recommendation is to progress to dual therapy with either a sulfonylurea, thiazolidinedione, DPP-4 inhibitor, SGLT2 inhibitor, GLP-1 receptor agonist, or basal insulin, plus metformin (American Diabetes Association, 2016b). Subsequently, if goal HbA_{1c} is not reached after three months of dual therapy, triple therapy may be initiated, by adding another hypoglycemic oral agent or adding basal insulin (American Diabetes Association, 2016b). If after three months of triple therapy goal HbA_{1c} is still not reached, combination injectable therapy is recommended with basal insulin plus either mealtime insulin or a GLP-1 receptor agonist (American Diabetes Association, 2016b). Between 2010 and 2012, 84 percent of people with diabetes were taking one or more oral or injectable diabetes medications, or a combination of both (U.S. Department of Health and Human Services, 2014). Some medications, like metformin, are relatively inexpensive, but the price of insulin has increased by 197 percent over the past 11 years (Hua et al, 2016). There is no generic insulin available, despite the drug being used widely since 1922 (Greene & Riggs, 2015). After adjusting for population age and sex differences, average medical expenditures among people with diagnosed diabetes were 2.3 times higher than what expenditures would be in the absence of diabetes (American Diabetes Association, 2016a).

T2D is a largely preventable disease, and the epidemic rise of its incidence and prevalence calls for a paradigm shift in lifestyle and dietary patterns. The lack of consensus in major guidelines about diet recommendations for individuals with pre-diabetes or diabetes leaves providers hesitant in recommending a particular diet. However, a low-fat, whole foods, plant-based (WFPB) diet may be an excellent option. Current research demonstrates that a low-fat

WFPB diet addresses the underlying pathophysiology of T2D, and offers health benefits beyond glycemic control, including reduced risk for hyperlipidemia, ischemic heart disease, hypertension, certain types of cancer, and obesity (Melina, Craig, & Levin, 2016). A low-fat WFPB diet includes whole grains, legumes, vegetables, fruits, nuts, and seeds in their least processed state, excludes all animal products (such as meat, poultry, fish, dairy, or eggs), and has no known negative side effects. Since having diabetes doubles the risk for cardiovascular disease, a low-fat, WFPB diet may be especially important in mitigating risk for macro- and microvascular complications in individuals with pre-diabetes and T2D by lowering body weight, blood sugar, cholesterol and blood pressure (Jahangiri-Noudeh et al., 2014; Melina et al., 2016).

Effectiveness of low-fat, WFPB diet for weight loss

Overweight and obesity continue to be strong risk factors for developing T2D, and analysis of the data from the Nurses' Health Study (NHS), with more than 200,000 participants followed up to 40 years, recently displayed the strength of that association (Hruby et al., 2016). Through the first eight years of the NHS, the risk of diabetes incidence in women with high normal body mass index (BMI; 23-23.9) was 3.6 more times the risk of those with BMI less than 22. Furthermore, weight gain after 18 years of age was a strong risk factor: compared with those who maintained a stable body weight through the first eight years, the relative risk (RR) of diabetes was higher than 17 for those who gained 35 or more kilograms (Hruby et al., 2016). In the extended follow-up period, women with BMI of 35 or more versus less than 22 had an age-adjusted RR of 93.2 for developing diabetes (Hruby et al., 2016). Weight loss actually showed to be protective against the development of diabetes: 5 kilograms or more of weight loss since 18 years of age was associated with an almost 50% lower risk of developing diabetes (Hruby et al., 2016).

Turner-McGrievy et al. (2015) compared the effectiveness of plant-based diets for weight loss through a RCT of five different diets: plant-based, or a vegan diet (omitting all animal products), omnivorous diet (excluding no foods), semi-vegetarian diet (occasional meat intake), pesco-vegetarian diet (excludes meat except seafood), and vegetarian diet (excludes all meat and seafood but contains eggs and dairy products). Sixty-three participants were randomized into a dietary group and weight loss was measured through the course of the six-month study. Energy restrictions were not recommended in any diet group, and exercise was neither promoted nor discouraged: self-reported intentional physical activity (kcals/d) was not significantly different among the five groups. Meat intake had a dose-dependent response in the weight loss among the groups: the vegan group's mean weight change was -7.5%, which was significantly different from the omnivorous group weight change of -3.1% (*P*=0.03), from the semi-vegetarian group weight change of -3.2% (*P*=0.03), and from the pesco-vegetarian group weight change of -3.2% (*P*=0.03) (Turner-McGrievy et al., 2011). The weight loss results of this study demonstrating greatest weight loss among the vegan group to the least weight loss in the omnivorous group mirror the direction of other health-related outcomes demonstrated in several large non-randomized prospective cohort studies, including metabolic syndrome, cancer incidence, T2D, and all-cause mortality (Orlich et al., 2013; Rizzo, Sabate, Jaceldo-Siegl, & Fraser, 2011; Tantamango-Bartley, Jaceldo-Siegl, Fan, & Fraser, 2013; Tonstad et al., 2013).

Effectiveness of low-fat, WFPB on biomarkers for T2D

McDougall et al. (2014) describe the effects of a low-fat WFPB diet on several biomarkers for disease processes, most notably for T2D. In this retrospective analysis of the records of patients who attended a seven-day physician-supervised residential program from 2002 to 2011, statistically significant decreases were noted in cholesterol (total, HDL, and LDL), weight, systolic and diastolic blood pressure, blood glucose, creatinine, and blood urea nitrogen (McDougall et al., 2014). The 1,615 participants who entered the seven-day treatment program were fed a low-fat (≤10% of calories), high-fiber, high-carbohydrate (~80% of calories) diet free from any animal derived products (e.g. meat, fish, eggs, or dairy products) and free from isolated vegetable oils (e.g. olive, flaxseed, sunflower, rapeseed, etc.). After a seven-day period following this diet, with no other interventions, the median (interquartile range, [IQR]) weight loss was 1.4 (IQR=1.8) kilograms, the median (IQR) decrease in total cholesterol was 22(IQR=29) mg/dL, systolic blood pressure dropped by 18 mmHg, and diastolic blood pressure dropped by 11 mm Hg in patients who had elevated systolic and diastolic blood pressure at baseline (McDougall et al., 2014).

While these results are dramatic, there are significant limitations to McDougall's study. The study did not control for exercise, which could potentially affect the weight loss experienced by participants. The timeframe of the study was only seven days, which does not allow for extrapolation of long-term, sustained results. Because the population was self-selected, they were potentially more motivated than the general population to obtain changes in their diet and appearance, and therefore more likely to experience the maximum benefits of the diet. Also, blood glucose was not monitored as part of this study.

In a randomized controlled trial called the GEICO study, a plant-based nutrition program aimed to reduce body weight and cardiovascular risk in the corporate setting. The population studied was comprised of men and women over 18 years of age with a body mass index (BMI) ≥ 25 kg/m^2 and/or a previous diagnosis of T2D who were recruited through advertisements and group meetings at 10 GEICO corporate offices across the United States (Mishra et al., 2013). The 142 participants in the intervention group were asked to follow a low-fat (< 3 grams per serving) plant-based diet consisting of whole grains, vegetables, legumes, and fruits, and limiting added oils, with no restriction on energy intake for 18 weeks, and to avoid all animal products (meat, poultry, fish, dairy products, and eggs) (Mishra et al., 2013). They were also encouraged to favor foods with a low glycemic index, and low-fat plant-based meal options were made available to them at their work sites, along with educational classes, group support sessions, and cooking classes. Individuals at the control sites made no dietary changes, were given no dietary guidance, and no plant-based meal option was made available to them during the study. All participants were asked not to alter their exercise patterns during the 18-week study period, and to remain on their baseline medication regimen as prescribed by their primary care physicians, unless modified by those physicians.

Measurements taken at week zero (baseline) and week 18 included: body weight, blood pressure, plasma cholesterol and triglycerides, HDL and LDL cholesterol, and HbA_{1c} in participants with diabetes. Mean body weight decreased 2.9 kg in the intervention group and 0.06 kg in the control group ($P < 0.001$), BMI fell by 1.04 kg/m^2 in the intervention group, and 0.01 kg/m2 in the control group ($P < 0.001$), and weight loss of ≥ 5% of body weight was more frequent in the intervention group (37%) compared with the control group (11%; $P < 0.001$) (Mishra et al., 2013). Beyond body weight reduction, which has been proven to improve glycemic control, the intervention group experienced benefits in plasma lipid concentrations and blood pressure, which can help alleviate morbidity and mortality from cardiovascular events such a stroke and myocardial ischemia, for which T2D is a strong risk factor (ACCORD Study Group, 2016). Among the participants who completed the entire 18-week trial at GEICO, total cholesterol dropped 13.7 mg/dl in the intervention group and 1.3 mg/dl in the control group ($P <$ 0.0001), and LDL cholesterol fell 13 mg/dl in the intervention group and 1.7 mg/dl in the control group (*P* < 0.0001) (Mishra et al., 2013). HbA_{1c} fell by 0.6% after 18 weeks in the intervention group versus 0.08% in the control group (p=0.004) (Mishra et al., 2013).

Lee et al. (2016) compared a standard diabetic diet and a plant-based, brown-rice-centric diet and their effects on HbA_{1c} in two groups of Korean adult patients with diabetes on hypoglycemic medications with baseline HbA_{1c} levels 6-11%. The plant-based diet group (n=47) was asked to consume whole grains, vegetables, fruits, and legumes; furthermore, they were instructed to eat brown rice and avoid white rice, avoid highly processed food made of rice or wheat flour, avoid all animal food products, and favor low-glycemic index foods (i.e. legumes, green vegetables, and seaweed). Amount and frequency of food consumption, caloric intake, and portion sizes were not restricted, and participants were monitored over a 12-week period.

The control group (n=46) followed the treatment guidelines for diabetes recommended by the Korean Dietetic Association (KDA) in 2011, which includes foods from grains, meats, vegetables, fats and oils, milk, and fruits. Participants were asked to 1) restrict their individualized daily energy intake based on body weight, physical activity, need for weight control, and compliance; 2) total calorie intake comprised 50-60% carbohydrate, 15-20% protein (if renal function is normal), <25% fat, <7% saturated fat, minimal trans-fat intake, and ≤ 200 mg/day cholesterol (Y. M. Lee et al., 2016). Participants were asked to maintain their baseline exercise regimens, to record their daily food intake, and to maintain their current medication, though dose reduction was permitted when it was necessary according to a physician's judgment. Food intake was measured through unannounced phone calls where participants were asked to recall their last 24 hours of eating and dietary compliance was measured (Y. M. Lee et al., 2016).

Glycemic control was the primary endpoint of measurement, and the HbA_{1c} levels of both groups significantly decreased over time: -0.5% in the vegan diet group (*P*<0.01) and -0.2% in the KDA diet group ($p<0.05$) (Y. M. Lee et al., 2016). Furthermore, dieters with high compliance (followed the diet strictly >90% of the time) had more remarkable results, with -0.9% in the vegan group (n=14) and -0.3% in the KDA group (n=37) (P=0.017) (Y. M. Lee et al., 2016). These differences remained significant after adjusting for energy intake or waist circumference. Secondary endpoints measured included BMI, waist circumference, blood pressure, and lipid control. The BMI and waist circumference significantly reduced over the 12-week period only in the vegan diet group (P=0.027); however, there were no significant differences in the changes in systolic blood pressure, diastolic blood pressure, LDL-cholesterol level, or HDL-cholesterol level in both of the groups. It should be noted, however, that participants did not have abnormal average blood pressure or blood lipids at baseline, and significant changes in these endpoints have been seen in larger RCTs observing vegan diets (Le & Sabate, 2014; Yokoyama et al., 2014). The significant decrease in HbA_{1c} in the high compliance group of -0.9% suggests that individuals with pre-diabetes could lower their HbA_{1c} to a normal range with intensive diet intervention, and a low-fat WFPB diet could accelerate HbA_{1c} reduction in those with diabetes who need to lessen their HbA_{1c} significantly.

T2D and cardiovascular risk reduction with a low-fat, WFPB diet

Satija et al., (2016) analyzed data from three studies (The Nurses' Health Study [NHS], the Nurses' Health Study 2 [NHS2], and the Health Professionals Follow-Up Study [HPFS]) that followed more than 200,000 male and female health professionals across the United States for more than 20 years, regularly collecting information on their diet, lifestyle, medical history, and new disease diagnosis in an attempt to ascertain how gradations of adherence to different types of plant-based diets ("healthful" and "unhealthful") are associated with diabetes risk. The researchers found that having a diet that emphasized plant foods and that was low in animal foods was associated with a diabetes risk reduction of about 20%; moreover, they found that a plant-based diet (deemed "healthful" by the researchers) that mostly included whole grains, fruits, vegetables, and nuts had a 34% diabetes risk reduction (Satija et al., 2016). In contrast, individuals who followed plant-based diets that were classified as "unhealthful" (including large amounts of less nutrient-dense foods such as refined grains and sugar-sweetened beverages) had a 16% higher risk of diabetes (Satija et al., 2016). These associations were independent of BMI and other diabetes risk factors (Satija et al., 2016). Therefore, the study suggests that plant-based diets should be well planned and whole-food centric to protect against T2D. The researchers suggest that the "healthful" plant-based diet lowers the risk of T2D by being rich in dietary fiber, antioxidants, unsaturated fatty acids, and micronutrients such as magnesium, and by being low in saturated fat. The researchers also suggest that an underlying mechanism that is less understood in preventing diabetes may be in the gut microbiome. A "healthful" plant-based diet could promote a gut microbiome environment that promotes the metabolism of fiber and polyphenols and discourages the metabolism of bile acids, choline, L-carnitine, and amino acids, further reducing T2D risk (Glick-Bauer & Yeh, 2014; Satija et al., 2016). More research on this topic is needed.

The prospective epidemiological Adventist studies (Adventist Mortality Study [AMS; *n*=22,940], Adventist Health Study-1 [AHS-1; *n*=34,198], and Adventist Health Study-2 [AHS-2; *n*=96,194]) continue to provide researchers a wealth of information regarding associations between dietary patterns and health outcomes. Members of the Seventh-day Adventist religious denomination exhibit a variety of dietary habits, and many are vegetarian—vegan, lacto-ovo-vegetarians, semi-vegetarians, pesco-vegetarians—while about half of the population adhere to an omnivorous diet similar to the general population (Le & Sabate, 2014). Church doctrines recommend vegetarian practices and abstinence from the use of tobacco and alcohol; hence, this presents an ideal opportunity to compare various vegetarian dietary patterns, while controlling for known non-dietary confounders like alcohol and tobacco.

Le & Sabate's 2014 review aimed to compare the health effects of non-vegetarians to vegans and lacto-ovo-vegetarians to vegans using data from the Adventist cohorts. Non-vegetarians' mean BMI was 28.26 while vegans' mean BMI was 23.1 (P=0.0001) (Le & Sabate, 2014). Vegan Adventists were 49% less likely to have T2D compared to non-vegetarian Adventists, with analyses adjusted for age, sex, ethnicity, education, income, physical activity, television watching, sleep habits, alcohol use, and BMI (P=0.0001) (Le & Sabate, 2014). Furthermore, vegans were 75% less likely to experience hypertension than were non-vegetarians, adjusted for age, sex, and race (P=0.0001), and vegan males were 42% less likely to die from cardiovascular disease than non-vegetarians, had a 55% risk reduction for ischemic heart disease, and a 14% lower risk of all-cause mortality (P<0.05) (Le & Sabate, 2014). The review also aimed to compare the health status of lacto-ovo-vegetarians and vegans; while both lacto-ovo-vegetarians and vegans had reduced risk for hypertension, T2D, and obesity, vegans experienced greater risk reduction for those diseases (Le & Sabate, 2014).

Beyond weight loss and glycemic control: low-fat, WFPB diets and improved insulin sensitivity through less intramyocellular lipid accumulation

Low-fat WFPB diets have other potential qualities that can both prevent and manage T2D besides controlling blood glucose levels and mitigating risk factors like overweight and obesity. One possible alternative explanation for the success of this diet is the role of intramyocellular lipids (IMCL) in insulin resistance (IR) in skeletal muscle. It is widely accepted that IR, defined as impaired response in glucose uptake to physiological concentration of insulin, precedes the clinical presentation of diabetes (Kitessa & Abeywardena, 2016). Skeletal muscle, not a natural storage site for excess fat, will accumulate lipids when the number and size of adipocytes—the normal storage sites for excess fat—fails to store the excess dietary fat (Jo et al., 2009; Kitessa & Abeywardena, 2016). IR in skeletal muscle has been a focus of much research and review: skeletal muscle is the largest organ in the body and plays a critical role in glucose homeostasis, accounting for up to 40% of the body and for up to 80-90% of insulin-stimulated glucose clearance (Kitessa & Abeywardena, 2016). Insulin promotes glucose control by enhancing glucose uptake in skeletal muscle and other tissues, and by inhibiting glucose production in the liver (Samuel, Petersen, & Shulman, 2010; Samuel & Shulman, 2012). The two most commonly cited lipid intermediates for causing skeletal muscle IR are ceramides and diacylglycerol (DAG) in IMCLs, but the role of these intermediates in IR are under debate among researchers (Kitessa & Abeywardena, 2016).

Skeletal muscle IR is considered the primary defect that can be detected decades ahead of β-cell failure and hyperglycemia—the trademarks of T2D—and thus understanding the development of IR and creating remedial mechanisms for affected populations could provide an early and cost-effective solution that could stop the T2D epidemic (Kitessa & Abeywardena, 2016). While the "holy grail" of unraveling the origin of IR in skeletal muscles has remained elusive to researchers as knowledge of the workings of the human cell grows more complex by the day, it is an established and undisputed fact that dietary fatty acid supply is at the core of lipid-induced IR in skeletal muscle, and that maintaining the dynamic lipid balance is key to human health (Kitessa & Abeywardena, 2016; Li, Xu, Zhang, Yi, & Cichello, 2015). As Kitessa and Abeywardena (2016) explain, "[dietary fatty acid supply] is the one lever that can be dialed up/down to regulate the flow of lipid intermediates into organs not intended for lipid storage" (p.

466). In a Japanese study, 37 non-obese male participants were fed a high-fat diet (60% calories from fat, 45% of which was saturated fat) and after three days and IMCL levels were increased by 30% ($p < 0.01$) (Sakurai et al., 2011).

Furthermore, a study of early weight-loss intervention (from hypocaloric diets) on insulin-resistant offspring of individuals with T2D supported the relationship between IMCL and skeletal muscle IR, with weight loss that coincided with 30% reduction in IMCL producing a 60% increase in insulin sensitivity (Petersen et al., 2012). Since vegan diets produce the most weight loss and typically include very little saturated fat, it follows that a low-fat WFPB diet would act as a protective mechanism against the accumulation of IMCL in skeletal muscle, which leads to IR and inevitably T2D (Turner-McGrievy et al., 2011). Interestingly, while the mechanism of action of metformin (the current first-line oral medication for T2D) remains unclear, it effectively reduces fatty acid accumulation in skeletal muscle and this is a potential reason for its efficacy in improving insulin sensitivity (Wang et al., 2014).

Persistent organic pollutants and the potential for increased risk of diabetes

Another factor that offers protection against T2D for those who consume a low-fat WFPB diet is their minimized consumption of persistent organic pollutants (POPs), which are known to cause endocrine disruption. POPs, which are either man-made or by-products of industrial processes, are hazardous chemicals that are resistant to environmental decay through chemical, biological, and photolytic means. POPs are omnipresent in the environment and food chain and are able to bio-accumulate in human and animal tissue, and have substantial impacts on human health and the environment (Ngwa, Kengne, Tiedeu-Atogho, Mofo-Mato, & Sobngwi, 2015; Ruzzin, 2012). Human exposure to POPs occurs primarily through the consumption of animal fats like fatty fish, meat, and dairy products (Ngwa et al., 2015). Initially, they were notorious for their ability to affect reproduction and promote cancer, but recent studies have highlighted their ability to amplify development of metabolic diseases like obesity and T2D (Ruzzin, 2012). Cross-sectional studies have shown the association between serum concentrations of POPs and prevalence of diabetes, and these have been supported by prospective and experimental data (D. H. Lee et al., 2006; D. H. Lee, Porta, Jacobs, & Vandenberg, 2014; Ngwa et al., 2015).

POPs have been described as "obesogens," functionally defined as chemicals that shift homeostatic metabolic set-points, interrupt appetite controls, disturb lipid homeostasis to promote adipocyte hypertrophy, stimulate adipogenic pathways that encourage adipocyte hyperplasia, or otherwise alter adipocyte differentiation during development (D. H. Lee et al., 2014). Animal products may proffer a double-edged sword to those at risk for T2D through excess dietary saturated fat and altering metabolic pathways via POPs.

Management strategies: low-fat WFPB as a prevention tool and adjunct therapy for T2D

As the evidence continues to mount in support of a low-fat WFBP diet for the prevention and adjunct therapy to standard treatment of T2D, and as the popularity of plant-based nutrition has soared in recent years, clinicians should consider "prescribing" plant-based diets to their patients at risk for T2D and patients currently living with the disease. Not only has the diet proven its benefits for weight loss, it also has infinite advantages related to the vast portfolio of nutrients found in plant foods: phytochemicals and fibers are possibly the two most health-promoting and disease-preventing categories of nutrients, and plants are the only sources of these nutrients (Hever, 2016). Furthermore, the side effects of oral hypoglycemic drugs like thiazolidinediones can include liver disease, fluid retention, weight gain, increased risk for fractures, increased risk for bladder cancer, hypoglycemia, headache, stomach upset, and diarrhea, whereas there are no known negative side effects to a low-fat WFPB diet (Chandran, 2016; Sinha & Ghosal, 2013). As Dr. Hever noted in her 2016 Physician's Guide to Plant-Based Diets, lifestyle change as primary prevention has been estimated to save up to 70- 80% of health care costs because 75% of health care spending in the United States goes to treat individuals with chronic conditions (National Center for Chronic Disease Prevention and Health Promotion, 2009). Considering the effectiveness of the intervention, the minimal side effects, and the cost savings in the midst of a health care cost crisis, it is a logical conclusion to offer plant-based diets to patients with pre-diabetes as a first-line therapy in the clinical setting, and as an adjunct to standard therapy for those currently living with the disease.

There is a strong and continuous association between elevated baseline HbA_{1c} and subsequent diabetes (American Diabetes Association, 2016b). In a systematic review of 44,203 individuals from 16 cohort studies with follow-up time period averaging 5.6 years, those individuals with an HbA_{1c} between 5.5-6.0 % had a significant increased risk of diabetes (5-year incidence from 9% to 25%) (American Diabetes Association, 2016b). A HbA_{1c} of 6.0-6.5% had a 5-year risk of developing diabetes between 25% and 50% and a relative risk 20 times higher compared with a HbA_{1c} of 5.0% (American Diabetes Association, 2016b). The American Diabetes Association (2016) already recommends testing to assess risk for future diabetes in asymptomatic people who are overweight or obese (BMI ≥25 kg/m^2 or ≥23 kg/m^2 in Asian Americans) and who have one or more additional risk factors for diabetes, particularly tobacco use. Every patient who has a $HbA_{1c} \geq 5.5\%$ should be educated about the benefits of a low-fat, WFPB diet, and at a minimum be given resources to learn more about the diet and the importance of tightening blood glucose control now in order to prevent the future occurrence of diabetes. Individuals already diagnosed with the disease, regardless of their current treatment methods, should also be educated about making the switch to a low-fat, WFPB diet, but should monitor their blood glucose very carefully as they begin the diet, as blood glucose can drop quickly, especially while concurrently taking hyperglycemia medications.

Changing practice to implement recommendation of a low-fat, WFPB diet and current barriers to implementation

Kaiser Permanente, the nation's leading nonprofit integrated health plan that serves 10 million people, has made bold strides toward promoting the recommendation of a plant-based diet to all patients, especially those with high blood pressure, diabetes, cardiovascular disease, and/or obesity (Tuso, Ismail, Ha, & Bartolotto, 2013). Kaiser Permanente has sought to educate their health care providers on the importance of a plant-based diet as a first-line treatment for chronic illness, and blames lack of health care provider awareness and a lack of patient education resources as the culprit for why plant-based diets are not routinely touted by clinicians.

V. Lee, McKay & Ardern (2015) assessed awareness, barriers, and promoters of plant-based diet use for management of T2D for the development of an appropriate educational program in 98 patients and 25 health care providers in a diabetes education center in Canada. The results reflected that 89% of patients were not aware of using a plant-based diet for the prevention and management of T2D and many of them cited low confidence in adopting a plant-based eating pattern (V. Lee, McKay, & Ardern, 2015). However, and significantly, two-thirds of the patients expressed willingness to follow a plant-based diet for the short-term and expressed interest in attending a vegetarian education program, contrary to the belief cited by most diabetes educators that patients would find a plant-based diet too difficult to follow and would not find it an acceptable recommendation (V. Lee et al., 2015). One particular advantage to following a low-fat WFPB diet is that dieters may eat ad libitum and still reap the benefits of weight loss; this factor can help motivate those who feel that diets are too difficult to follow due to hunger (McDougall et al., 2014; Trepanowski & Varady, 2015).

Nurse practitioner leadership in WFPB diet interventions in primary care and corporate settings

Group visits are planned medical appointments in a group setting of five to 20 participants. Visits include some elements of an individual patient visit, like vital signs, history, and some elements of physical exam, in addition to patient education and group support. Group visits are led by health care providers, and nurse practitioners working in primary care settings who are educated about the benefits of a low-fat, WFPB diet are the ideal leaders for these types of patient care models. Improvements in patients' disease-specific outcomes have been observed in multiple group visit studies: through the group visit model, patients are equipped to self-manage their disease, and report increased levels of disease-specific knowledge (Montoya, Sole, & Norris, 2016).

When seeing patients in a traditional primary care setting, nurse practitioners may assess pre-diabetic and diabetic patients' willingness to adopt a major lifestyle change in order to improve their health. Norcross, Krebs & Prochaska (2011) identified stages of change to assist in assessing an individual's readiness for change in behavior. Precontemplation is the stage in which there is no intention to change behavior in the foreseeable future, and most people will fall into this stage of change at any given time regarding a major lifestyle change. Some individuals will be in a contemplation stage of change, where they are aware a problem exists and are seriously thinking about overcoming it, or in a preparation stage of change, where individuals are intending to take action in the next month and are reporting some small behavioral changes (Norcross, Krebs, & Prochaska, 2011). Individuals in a contemplation or preparation stage of change can be identified while taking a thorough history, and may be receptive to make and sustain a major lifestyle change to a low-fat, WFPB diet. Once patients are identified to be in a stage of contemplation or preparation, they may be asked to join in a group visit to learn more about the disease process of pre-diabetes or diabetes, and learn about how a low-fat, WFPB diet can improve their health outcomes.

A group visit model with one long initial visit (three to four hours with a communal meal served) and three one-hour weekly follow up visits may be enough to create and sustain a long-term diet change if patients see positive results in this time frame and if they receive adequate support from the provider and the group. Patients' family members may be encouraged to join in the visit to be able to support their loved one in their diet change or implement the diet as well. During the first visit, patients may have their weight recorded as well as their blood pressure, fasting lipid panel and fasting blood glucose, to be able to compare these parameters after the intervention. At each weekly visit, a complete shopping list and meal plan may be provided for patients. Education about how to read food labels may occur in the first meeting, and an online forum can be set up for questions that may arise during the week. Group members should be encouraged to support one another and even dine together during the week if possible. Cooking classes and grocery store tours can be included in the group education to help individuals improve their health and nutrition literacy. Most large insurance companies will reimburse practices for group visits for patients with chronic diseases.

Worksite plant-based nutrition programs have been well-accepted by participants, as was the case with the GEICO study. Worksites offer convenient and supportive environments for health promotion programs because there is no travel time and participants often have common interests and goals, as well as a pre-existing camaraderie (Katcher, Ferdowsian, Hoover, Cohen,

& Barnard, 2010). During the GEICO study, which took place in a corporate environment typical of major businesses, participants in the vegan diet group reported increased satisfaction with their diet and improvements in physical functioning, mental health, vitality, and work productivity compared to control group participants (Katcher et al., 2010). This satisfaction, along with the significant health benefits from the plant-based diet group mentioned previously, suggest that worksite interventions could offer a path forward in getting more people to try plant-based diets (Mishra et al., 2013). Many large corporate work sites have onsite health care centers that are operated by nurse practitioners who are perfectly suited to leading these interventions as they can monitor patient progress and educate individuals on how to implement dietary changes, so long as they are educated on the WFPB diet.

Useful resources for health care provider use with patients are now widely available. The popular documentary, *Forks Over Knives* (www.ForksOverKnives.com) introduces and explains the power of plant-based diets for patients and the family members of patients. Low-fat WFPB recipes and meal plans are available at no cost at www.21DayKickstart.org. Clinicians may earn continuing education credits on plant-based nutrition at no cost at www.NutritionCME.org. The Physicians Committee for Responsible Medicine has created a low-fat WFPB diet graphic called the Power Plate, a useful tool for explaining the components of this dietary pattern, which divides the plate into four evenly divided sections: fruits, vegetables, grains, and legumes. This resource may help simplify what many people misperceive as a complicated way of eating, and ensures individuals get a healthy amount of protein, carbohydrate, and micronutrients.

As health care costs concurrently rise year after year with the incidence and prevalence of diabetes, the time is now for clinicians to recommend a low-fat WFPB diet to all of their patients, as a preventative measure for those with pre-diabetes and as an adjunct to standard therapy for those living with T2D. The diet can help prevent T2D as well as slow or stop the progression of the disease by controlling blood sugar naturally and with no known negative side effects. The benefits of the diet are clear, but more education is needed for both clinicians and their patients on these benefits and how to effectively and sustainably promote diet change. The future of health care is preventative, and a low-fat WFPB diet could save monumental medical costs, but more importantly, it could save many from suffering and ultimately dying from T2D and its sequelae.

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