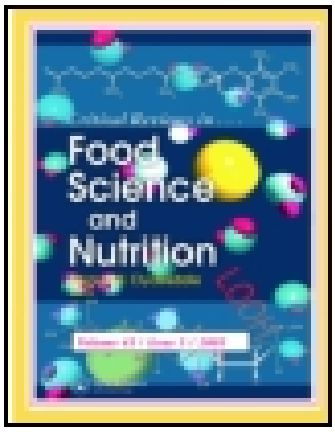

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Veganism is a viable alternative to conventional diet therapy for improving blood lipids and glycemic control

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Veganism is a viable alternative to conventional diet therapy for improving blood lipids and glycemic control

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Running head: Veganism for improving metabolic disease risk

Abstract

The American Diabetes Association (ADA) and the National Cholesterol Education Program (NCEP) have each outlined a set of dietary recommendations aimed at improving glycemic control and blood lipids, respectively. However, traditional vegan diets (low-fat diets that proscribe animal product consumption) are also effective at improving glycemic control, and dietary portfolios (vegan diets that contain prescribed amounts of plant sterols, viscous fibers, soy protein, and nuts) are also effective at improving blood lipids. The purpose of this review was to compare the effects of traditional vegan diets and dietary portfolios with ADA and NCEP diets on body weight, blood lipids, blood pressure, and glycemic control. The main findings are that traditional vegan diets appear to improve glycemic control better than ADA diets in individuals with type 2 diabetes mellitus (T2DM), while dietary portfolios have been consistently shown to improve blood lipids better than NCEP diets in hypercholesterolemic individuals.

Keywords: cardiovascular disease, type 2 diabetes, blood pressure, body weight

1. Introduction

Among American adults, 82 million people have one or more types of cardiovascular disease (CVD), and 25 million people have diabetes mellitus (Roger et al., 2012). These diseases are expected to become only more prevalent in the upcoming decades (Heidenreich et al., 2011; Shaw et al., 2010). Dietary treatment is considered a first line of defense for both diseases. Appropriately, the National Cholesterol Education Program (NCEP) and the American Diabetes Association (ADA) have each devised a set of dietary recommendations aimed at improving blood lipids and glycemic control, respectively (National Cholesterol Education Program, 2002; Franz et al., 2003). The main dietary recommendations from the NCEP are that 50-60% of energy should come from carbohydrate, 15% energy from protein, 25-35% energy from fat (<7% energy from saturated fat), and that dietary cholesterol intake should be <200 mg/d (National Cholesterol Education Program, 2002). The main dietary recommendations from the ADA are similar: 60-70% of energy should come from carbohydrate and monounsaturated fat, 15-20% energy from protein, <7% energy from saturated fat, and dietary cholesterol intake should be <200 mg/d (Franz et al., 2003).

Unfortunately, diets that follow the recommendations of the NCEP (hereafter referred to as "NCEP diets") and the ADA (hereafter referred to as "ADA diets") appear to be only moderately effective in the long term at achieving their respective lipid- and glucose-lowering targets. For instance, an NCEP diet failed to lower LDL-C in hypercholesterolemic individuals at 24 weeks (-3%; P = 0.06) (Jenkins et al., 2011), while an ADA diet failed to lower glycated hemoglobin

(Hb A_{1c}) (0.01 percentage point increase; $P > 0.05$) or blood glucose (-4%; $P > 0.05$) in individuals with type 2 diabetes mellitus (T2DM) at 74 weeks (Barnard et al., 2009b). These findings are not particularly surprising when considering that the success of these diets are largely predicated on an individual's ability and willingness to measure and limit food intake. In contrast, individuals are often able to achieve the main dietary goals of the NCEP and the ADA (i.e. reducing saturated fat and dietary cholesterol intake) on a vegan diet without needing to limit food consumption (Barnard et al., 2009c). Moreover, vegan diets have been shown to be comparable in acceptability and adherence to both NCEP and ADA diets (Barnard et al., 2009c; Barnard et al., 2004). Together, these results suggest that that vegan diets may be viable alternatives to NCEP and ADA diets. Several investigations have tested this hypothesis by comparing either a traditional vegan diet (a low-fat diet that disallows animal product consumption) or a dietary portfolio (a vegan diet with prescribed amounts of plant sterols, viscous fibers, soy protein, and nuts) to either an NCEP or ADA diet. Specifically, dietary portfolios have been compared to NCEP diets regarding cardiovascular parameters (Jenkins et al., 2011; Jenkins et al., 2001; Jenkins et al., 2003a; Jenkins et al., 2003b; Jenkins et al., 2005), while traditional vegan diets have been compared to both NCEP and ADA diets regarding cardiovascular and glycemic parameters (Barnard et al., 2009b; Nicholson et al., 1999; Barnard et al., 2005; Barnard et al., 2006; Turner-McGrievy et al., 2007). The purpose of this review is to summarize the findings of these investigations.

2. Methods

A Pubmed search was conducted using the key words “vegan,” “vegetarian,” “low-fat vegetarian,” “vegetarianism,” “plant-based diet,” “plant diet,” and “dietary portfolio” and limited

to adults, clinical trials, randomized controlled trials, English, and humans. Additional trials were identified using the references listed in these manuscripts. These searches yielded 239 potentially relevant articles. Trials were included in this review if 1) a vegan diet (prohibiting all animal product consumption) was compared to an NCEP or ADA diet that permitted at least some animal product consumption (meats, dairy products, eggs, or some combination); 2) the primary outcome was related to body weight, blood lipids, blood pressure, or glycemic control; and 3) there were no cointerventions that likely affected the primary outcome (e.g. exercise). Eight trials met all of the inclusion criteria.

3. Dietary interventions

3.1 Traditional vegan diets

The traditional vegan diets featured in this review were similar to one another regarding macronutrient composition (~10% energy from fat, 10-15% protein, ~75% carbohydrate), prescribed foods (vegetables, fruits, whole grains, and lentils), and proscribed foods (animal products and fatty foods, such as added oils, avocados, nuts, and seeds) (Barnard et al., 2009b; Nicholson et al., 1999; Barnard et al., 2005; Barnard et al., 2006; Turner-McGrievy et al., 2007). One trial provided all lunches and dinners to subjects, while subjects were responsible for preparing their own breakfasts (Nicholson et al., 1999). This trial (Nicholson et al., 1999) permitted subjects to consume additional food at any time during the day so long as they adhered to their prescribed dietary guidelines. The other trials offered dietary counseling but did not provide any food (Barnard et al., 2009b; Barnard et al, 2005; Barnard et al., 2006; Turner-McGrievy et al., 2007). Energy intake was not restricted in any of the trials examining

traditional vegan diets (Barnard et al., 2009b; Nicholson et al., 1999; Barnard et al., 2005; Barnard et al., 2006; Turner-McGrievy et al., 2007).

3.2 Dietary portfolios

As mentioned above, dietary portfolios contain prescribed amounts of plant sterols (1-1.2 g/1000 kcal), viscous fibers (8.2-9.8 g/1000 kcal), soy protein (16.2-22.7 g/1000 kcal), and nuts (14-16.6 g/1000 kcal) (Jenkins et al., 2011; Jenkins et al., 2003a; Jenkins et al., 2003b; Jenkins et al., 2005). The majority of the trials that examined dietary portfolios in this review disallowed any animal product consumption (Jenkins et al., 2011; Jenkins et al., 2003a; Jenkins et al., 2005), although one trial provided eggs (1/wk) and butter (9 g/d) to balance the saturated fat and dietary cholesterol intakes of the dietary portfolio group with those of the NCEP diet group (Jenkins et al., 2003b). One trial examined a vegan diet designed to approximate what human ancestors may have consumed 5-7 million years ago (Jenkins et al., 2001). This diet was high in plant sterols, viscous fibers, soy protein, and nuts, although specific intakes of these foods were not prescribed. Nonetheless, this diet will be categorized as a dietary portfolio for the purpose of this review. One trial provided all foods to subjects (Jenkins et al., 2001), while three trials provided all foods with the exception of fruits and low-calorie, nonstarch-containing vegetables, which the subjects were instructed to obtain from local stores (Jenkins et al., 2003a; Jenkins et al., 2003b; Jenkins et al., 2005). One trial offered dietary counseling but did not provide any food (Jenkins et al., 2011). Each of the trials that examined a dietary portfolio encouraged weight maintenance (Jenkins et al., 2011; Jenkins et al., 2001; Jenkins et al., 2003a; Jenkins et al., 2003b; Jenkins et al., 2005).

4. Vegan diets versus conventional diets: Effects on chronic disease risk parameters

Each of the four following subsections (body weight, blood lipids and apolipoproteins, blood pressure, and glycemic control) is divided into three parts: The first part briefly explains how these parameters relate to CVD and T2DM. The second part compares the effects of vegan, NCEP, and ADA diets on these parameters. The third part explains the proposed mechanisms for how a vegan diet modulates these parameters.

4.1 Body weight

Excess adipose tissue increases the risk of developing CVD by promoting dyslipidemia, hypertension, impaired glycemic control, inflammation, obstructive sleep apnea/hypoventilation, and a prothrombotic state (Poirier et al., 2006). Weight loss has been associated with numerous improvements to the cardiovascular system, which are discussed in an excellent review (Poirier et al., 2006). Regarding T2DM, excessive weight gain promotes pathological changes in adipose tissue that ultimately result in systemic insulin resistance and β-cell dysfunction (Cusi, 2010). Weight loss helps reverse these pathological changes (Bays et al., 2008), which in turn improves glycemic control in diabetics, and slows or prevents the development of T2DM in susceptible individuals (Klein et al., 2004).

Preliminary evidence suggests that traditional vegan diets may be more effective than NCEP diets and ADA diets at reducing body weight when energy intake is unrestricted (Table 1). One trial reported that a traditional vegan diet lowered body weight in overweight (BMI 25-29.9

kg/m$^{2)}$ and obese (BMI ≥30 kg/m^2) postmenopausal women to a greater extent than an NCEP diet at 14 wk (-6% vs. -4%, respectively) (Barnard et al., 2005) and 104 wk (-4% vs. -1%) (Turner-McGrievy et al., 2007). Energy reduction from baseline was similar between groups at 14 wk (Barnard et al., 2005) and was not measured at 104 wk (Turner-McGrievy et al., 2007). Another trial compared a traditional vegan diet with an ADA diet in men and women with T2DM (Barnard et al., 2009b; Barnard et al., 2006). Energy intake was unrestricted in the vegan group, but overweight and obese subjects in the ADA group (47 out of 50 subjects) were prescribed daily energy intake deficits of 500-1000 kcal. Despite this unequal energy intake prescription, the vegan group voluntarily reduced energy intake by a similar magnitude to the ADA group and lost more weight than the ADA group at 22 wk when medication changes were accounted for (-6% vs. -3%, respectively) (Barnard et al., 2006). Weight loss was well maintained for both the vegan group (-5%) and the ADA group (-3%) after an additional year of study (Barnard et al., 2009b), although the between-group difference was no longer statistically significant. Of interest, the two studies that reported greater weight loss for the vegan group compared to the ADA group despite similar reductions in energy intake also reported that the groups had similar self-reported physical activity (Barnard et al., 2005; Barnard et al., 2006), pedometer readings (Barnard et al., 2006), and resting metabolic rate (Barnard et al., 2005). A feeding trial reported that a traditional vegan diet lowered body weight in men and women with T2DM to a greater extent than an ADA diet at 12 wk (-7% vs. -4%, respectively); however, the vegan group was provided less dietary energy (1050 kcal/d) than the ADA group (1200 kcal/d) (Nicholson et al., 1999).

Each of the trials examining a dietary portfolio encouraged weight maintenance (Jenkins et al., 2011; Jenkins et al., 2001; Jenkins et al., 2003a; Jenkins et al., 2003b; Jenkins et al., 2005). Consequently, weight loss was minimal in these studies, and none of the studies reported a difference in weight loss between the dietary portfolio group and the NCEP group (Jenkins et al., 2011; Jenkins et al., 2001; Jenkins et al., 2003a; Jenkins et al., 2003b; Jenkins et al., 2005) (Table 1).

The low fat content, high fiber content, and low glycemic index of traditional vegan diets are likely the main dietary factors responsible for weight loss (Barnard et al., 2006; Turner-McGrievy et al., 2011). Reducing fat intake and increasing fiber intake lowers energy density (Berkow and Barnard, 2006), while reducing the glycemic index and increasing fiber intake improves satiety (Berkow and Barnard, 2006; Brand-Miller et al., 2002). Whether a dietary portfolio is an effective dietary strategy for promoting weight loss in overweight and obese individuals is an important question that warrants further investigation.

4.2 Blood lipids and apolipoproteins

Blood lipids and apolipoproteins affect the likelihood of developing CVD mainly through their contribution (either favorable or unfavorable depending on the lipid parameter in question) to the development of atherosclerosis (Lusis et al., 2004), and improvements in these lipid parameters have been associated with reduced CVD risk (Arsenault et al., 2011). While this is true for both nondiabetics and diabetics, the latter are an interesting case due to their higher tendency to have

a particular form of dyslipidemia characterized by high serum triglyceride concentrations and low HDL-C concentrations (Mooradian, 2009).

Only two trials have compared the lipid-altering effects of a traditional vegan diet and an ADA diet (Barnard et al., 2009b; Nicholson et al., 1999; Barnard et al., 2006) (Table 1). Both trials reported equal reductions in serum triglycerides between the vegan group and the ADA group (Barnard et al., 2009b; Nicholson et al., 1999; Barnard et al., 2006). Nicholson et al. (1999) did not find a between-group difference in total cholesterol reduction but did note a greater reduction in HDL-C for the vegan group (-17% vs. -2%) at 12 wk. In contrast, Barnard et al. (2009b; 2006) reported that the vegan group experienced greater reductions in total cholesterol than the ADA group at 22 wk (-18% vs. -10%, respectively) and 74 wk (-11% vs. -3%, respectively), and there was no between-group difference in HDL-C reduction at either time point. Both studies enrolled individuals with T2DM, and both studies reported greater reductions in medication usage from baseline to end of study in the vegan group, but only the Barnard et al. study (2009b; 2006) accounted for medication changes in its statistical analysis. When Barnard et al. (2009b; 2006) also performed an intention to treat analysis that did not account for medication changes, the between-group difference in total cholesterol reduction was abolished. This suggests that the decision to not account for medication changes in the Nicholson et al. study (1999) may explain why a between-group difference in total cholesterol reduction was not observed. Barnard et al. (2009b; 2006) observed a greater decrease in LDL-C in the vegan group at 22 wk (-21% vs. -9%) and 74 wk (-13% vs. -3%), while Nicholson et al. (1999) noted no between-group difference on

this marker. No studies to date have compared the effects of traditional vegan diets, NCEP diets, and ADA diets on apolipoproteins.

Three metabolically controlled trials, each lasting 4 wk, reported superior effects for a dietary portfolio compared to an NCEP diet in terms of reduction in total cholesterol (average over three trials: -24% vs. -8%, respectively), LDL-C (-31% vs. -10%), apolipoprotein B (-25% vs. -7%), and the ratio of apolipoprotein B:A1 (-19% vs. 0%) in hypercholesterolemic (LDL-C >158 mg/dL) men and postmenopausal women (Jenkins et al., 2003a; Jenkins et al., 2003b; Jenkins et al., 2005) (Tables 1 and 2). Comparable results were observed when a vegan diet similar in composition to a dietary portfolio was compared to an NCEP diet for 2 wk (Jenkins et al., 2001). A dietary portfolio has also yielded more-favorable lipid-altering effects compared to an NCEP diet under free-living conditions (Jenkins et al., 2011). Specifically, men and postmenopausal women with above-optimal LDL-C (135-205 mg/dL for men and 116-178 mg/dL for women) experienced greater reductions in total cholesterol (-10% vs. -1%), LDL-C (-13% vs. -3%) and apolipoprotein B (-11% vs. 0%) when advised to consume a dietary portfolio than those advised to consume an NCEP diet (Jenkins et al., 2011). Whether examined under metabolically-controlled or free-living conditions, a dietary portfolio and an NCEP diet appear to have comparable effects on HDL-C, serum triglycerides, and apolipoprotein A1 (Jenkins et al., 2011; Jenkins et al., 2001; Jenkins et al., 2003a; Jenkins et al., 2003b; Jenkins et al., 2005).

Compared to omnivorous diets, vegan diets are often lower in total fat, saturated fat, and dietary cholesterol, resulting in less intestinal absorption and subsequent conversion to serum cholesterol

(Ferdowsian and Barnard, 2009). Vegans also tend to consume high amounts of several foods that have been associated with lower serum cholesterol concentrations, including fruits, vegetables, whole grains, soy, and nuts (Haddad et al., 1999; Larsson and Johansson, 2005; Keinan-Boker et al., 2002; Larsson and Johansson, 2002; Djousse et al., 2004; Harris and Kris-Etherton, 2010; Jenkins et al., 2010; Griel and Kris-Etherton, 2006).

Low intakes of total fat, saturated fat, and dietary cholesterol together account for approximately one-third of the 29-35% LDL-C reduction observed with a dietary portfolio under metabolic conditions, while the remaining two-thirds of this reduction can be attributed to the consumption of plant sterols, viscous fibers, soy protein, and nuts (Jenkins et al., 2003a; Jenkins et al., 2003b; Jenkins et al., 2005). Plant sterols interfere with intestinal cholesterol absorption (Trautwein et al., 2003), while viscous fibers increase fecal bile acid loss (Salas-Salvadó et al., 2006). Soy protein displaces saturated fat and dietary cholesterol and inhibits cholesterol synthesis (Jenkins et al., 2010). The fatty acid profile (high in unsaturated fat, low in saturated fat) and fiber content of nuts are believed to account for much of their cholesterol-lowering ability, although other nutrients may play an additional role (Griel and Kris-Etherton, 2006).

4.3 Blood pressure

Hypertension induces a remodeling of the vasculature – characterized by growth, apoptosis, inflammation, and fibrosis – that eventually results in cardiovascular complications (Intengan and Schiffrin, 2001). A reduction of systolic blood pressure by 10 mm Hg or diastolic pressure by 5 mm Hg reduces the occurrence of cardiovascular events (Law et al., 2009). Proper blood

pressure control is particularly important in individuals with T2DM, as they are 2 to 3 times as likely to develop CVD at every level of systolic blood pressure (Stamler et al., 1993). That being said, most of the reduction in cardiovascular risk associated with lowering blood pressure in individuals with T2DM is achieved once a target goal of systolic blood pressure equal to 140 mm Hg has been met (Friedewald et al., 2010).

Each of the trials that compared a traditional vegan diet with an ADA diet reported similar reductions in systolic and diastolic blood pressure (Barnard et al., 2009b; Nicholson et al., 1999; Barnard et al., 2006) (Table 2). Likewise, each of the trials that compared a dietary portfolio with an NCEP diet reported similar reductions in systolic and diastolic blood pressure (Jenkins et al., 2011; Jenkins et al., 2001; Jenkins et al., 2003a; Jenkins et al., 2003b; Jenkins et al., 2005).

Possible mechanisms that may explain a vegan diet's ability to lower blood pressure include a reduction in body weight and a reduction in blood viscosity (due to low intakes of total and saturated fat as well as a high ratio of intake of polyunsaturated to saturated fat) (Berkow and Barnard, 2005). Increased intakes of fruits, vegetables, potassium, antioxidants, and soy protein may also influence blood pressure (Berkow and Barnard, 2005).

4.4 Glycemic Control

Diabetes is defined by a lack of proper glycemic control that results in hyperglycemia, and improving this control is of first priority when treating this disease. Regarding the prevention and treatment of microvascular complications, intensive glycemic control appears to be superior

to modest glycemic control (American Diabetes Association, 2012). Intensive glycemic control also appears to lower CVD risk in newly diagnosed individuals with T2DM, but this benefit does not appear to extend to individuals with long-established T2DM (American Diabetes Association, 2012). In addition, the added benefits of intensive glycemic control should be weighed against the increased risk of developing hypoglycemia (American Diabetes Association, 2012).

One trial compared the glycemic effects of a traditional vegan diet and an NCEP diet in overweight and obese postmenopausal, nondiabetic women (Barnard et al., 2005) (Table 3). The vegan group lowered fasting serum glucose by 7% compared to a 2% reduction for the NCEP group, but this difference failed to reach statistical significance ($P = 0.10$), possibly due to low baseline values (99 mg/dL). The reduction in fasting serum insulin was similar between groups (Barnard et al., 2005). Two trials compared the glycemic effects of a traditional vegan diet and an ADA diet in men and women with T2DM (Barnard et al., 2009b; Nicholson et al., 1999; Barnard et al., 2006). Nicholson et al. (1999) reported that the vegan diet lowered fasting serum glucose more than the ADA diet (-28% vs. -12%, respectively) at 12 wk, but the reductions in Hb A_{1c} were similar between groups. This study did not account for reductions in medication usage (which were of greater number in the vegan group) in its statistical analysis, which may explain why a between-group difference in Hb A_{1c} reduction was not observed (Nicholson et al., 1999). Barnard et al. (2009b; 2006) found that a vegan diet reduced Hb A_{1c} to a greater extent than an ADA diet at 22 wk (-15% vs. -5%) and 74 wk (-5% vs. 0%) after accounting for

medication changes. Reductions in fasting serum glucose were not different between the vegan or ADA group at 22 wk or 74 wk (Barnard et al., 2009b; Barnard et al., 2006).

No trial to date has examined the glycemic effects of a dietary portfolio. This is a worthwhile topic for future research. The lipid-lowering ability of a dietary portfolio potentially could be of great benefit to individuals with T2DM given their 2- to 4-fold greater CVD risk. Establishing favorable glycemic effects for a dietary portfolio would add even more clinical relevance to this diet.

Vegan diets may improve glycemic control via a variety of mechanisms (reviewed in Barnard et al., 2009a). As mentioned above, vegan diets tend to reduce body weight, and the weight loss that occurs in response to vegan dieting correlates well with reductions in Hb A_{1c} at 22 wk ($r = 0.51$; $P < 0.0001$) and 74 wk ($r = 0.50$; $P = 0.001$) in men and women with T2DM (Barnard et al., 2009b; Barnard et al., 2006). Intramyocellular lipid concentrations, which are inversely correlated with insulin sensitivity (Petersen et al., 2004), are lower in vegans compared to omnivores (Goff et al., 2004). This may be due to the low fat content (especially saturated fat) of vegan diets (Greco et al., 2002; Sparks et al., 2005). Indeed, reducing saturated fat consumption has been shown to improve insulin sensitivity (Lovejoy, 2002; Riccardi et al., 2004). Vegan diets often have a low glycemic index, which lowers Hb A_{1c} by reducing body weight (Turner-McGrievy et al., 2011). The high fiber content of a vegan diet may improve glycemic control by reducing the rate of glucose intestinal absorption, reducing the rate of hepatic glucose production, and improving satiety, which reduces body weight and increases

insulin sensitivity (Jenkins et al., 1978; Weickert and Pfeiffer, 2008; Blackburn et al., 1984). Finally, the low intake of heme iron may reduce levels of serum ferritin (Cook, 1990), thereby improving insulin sensitivity (Hua et al., 2001).

5. Summary of findings

A traditional vegan diet appears to reduce body weight to a greater extent compared to an NCEP diet when food consumption is unrestricted (Barnard et al., 2005; Turner-McGrievy et al., 2007), and to a similar extent compared to an ADA diet with a prescribed energy deficit of 500-1000 kcal/d (Barnard et al., 2009b). The ability of a dietary portfolio to promote weight loss in individuals attempting to lose weight is presently unknown.

Total cholesterol and LDL-C are reduced by greater magnitudes on a traditional vegan diet compared to an ADA diet (Barnard et al., 2009b; Barnard et al., 2006), while both diets reduce serum triglycerides similarly (Barnard et al., 2009b; Nicholson et al., 1999; Barnard et al., 2006). Whether a traditional vegan diet reduces HDL-C to a greater (Nicholson et al., 1999) or similar extent (Barnard et al., 2009b; Barnard et al., 2006) compared to an ADA diet is currently unresolved. The effects of a traditional vegan diet on apolipoproteins are currently unknown. A dietary portfolio is more effective than an NCEP diet at reducing total cholesterol, LDL-C, apolipoprotein B, and the ratio of apolipoprotein B:A1 (Jenkins et al., 2011; Jenkins et al., 2001; Jenkins et al., 2003a; Jenkins et al., 2003b; Jenkins et al., 2005). The two diets have similar effects on HDL-C, serum triglycerides, and apolipoprotein A1 (Jenkins et al., 2011; Jenkins et al., 2001; Jenkins et al., 2003a; Jenkins et al., 2003b; Jenkins et al., 2005).

Traditional vegan diets lower systolic and diastolic blood pressure by comparable magnitudes compared to ADA diets (Barnard et al., 2009b; Nicholson et al., 1999; Barnard et al., 2006). A dietary portfolio and an NCEP diet also have similar effects on systolic and diastolic blood pressure (Jenkins et al., 2011; Jenkins et al., 2001; Jenkins et al., 2003a; Jenkins et al., 2003b; Jenkins et al., 2005).

In nondiabetics, a traditional vegan diet and an NCEP diet appear to lower fasting serum glucose and fasting serum insulin similarly (Barnard et al., 2005). The respective effects of a traditional vegan diet and an ADA diet on fasting serum glucose in individuals with T2DM are difficult to compare, because the studies to date have prescribed unequal energy intakes between the diet groups (Barnard et al., 2009b; Nicholson et al., 1999; Barnard et al., 2006). One trial observed a greater reduction in fasting serum glucose in the vegan group (Nicholson et al., 1999), while another trial noted similar between-group reductions in this parameter (Barnard et al., 2009b; Barnard et al., 2006). A traditional vegan diet appears to lower Hb A_{1c} to a greater extent compared to an ADA diet (Barnard et al., 2009b; Barnard et al. 2006). No studies to date have examined the glycemic effects of a dietary portfolio.

6. Conclusion

Both the NCEP and the ADA have recognized the important role of diet in improving cardiovascular and glycemic parameters by devising their own sets of dietary recommendations. However, clinical trials have identified traditional vegan diets and dietary portfolios as being potentially more beneficial at improving these parameters. Specifically, a traditional vegan diet may lower body weight more than an NCEP diet and may lower total cholesterol, LDL-C, and

Hb A_{1c} more than an ADA diet. A number of trials have consistently demonstrated that a dietary portfolio outperforms an NCEP diet in regards to reduction in total cholesterol, LDL-C, apolipoprotein B, and the ratio of apolipoprotein B:A1.

It is worth repeating that the vegan diets featured in this review did not simply proscribe animal product consumption but also were low in fat and, in the case of the dietary portfolios, contained prescribed amounts of cholesterol-lowering foods. Consequently, the findings that are summarized in this review apply to these specific vegan diets and cannot be generalized to all vegan diets.

Few firm conclusions can be made at the moment given the limited amount of available data, emphasizing the need for continued scientific inquiry. Some of the important questions that have yet to be addressed include 1) whether a traditional vegan diet improves glycemia better than an ADA diet in individuals with prediabetes, 2) whether a dietary portfolio lowers body weight in overweight and obese individuals by a greater magnitude in comparison to an NCEP diet in the absence of an energy intake prescription, and 3) whether a dietary portfolio improves glycemic control to a greater extent compared to an ADA diet in individuals with T2DM. While we await the answers to these questions and acknowledge that much research remains to be conducted, the present data suggest that traditional vegan diets and dietary portfolios may be considered as viable therapeutic alternatives to NCEP and ADA diets for individuals seeking improvement in cardiovascular and glycemic parameters.

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Table 1.

Vegan diets versus conventional diets: Effects on body weight and plasma lipids

Reference	Subjects	Trial length	Intervention groups	Body weight Change (%)		Total cholesterol Change (%)		LDL cholesterol Change (%)		HDL cholesterol Change (%)		Triglycerides Change (%)	
				Vegan	Conv.	Vegan	Conv.	Vegan	Conv.	Vegan	Conv.	Vegan	Conv.
Jenkins (2001)	n = 10, MF Age 38 ± 4 BMI 25 ± 1	2 wk	1. Vegan: Portfolio 2. NCEP Step 2	0%	↓1%	↓22%*	↓6%	↓33%*	↓7%	↓10%	↓2%	↓7%	↓10%
Jenkins (2003a)	n = 25, MF Age 60 ± 10 BMI 27 ± 3	4 wk	1. Vegan: Portfolio 2. NCEP Step 2	↓1%	↓1%	↓27%*	↓10%	↓35%*	↓12%	↓6%	↓7%	↓6%	↓5%
Jenkins (2003b)	n = 46, MF Age 59 ± 1 BMI 28 ± 1	4 wk	1. Vegan: Portfolio 2. NCEP Step 2	↓1%	0%	↓22%*	↓6%	↓29%*	↓9%	↓7%	↓10%	↓8%	↑10%
Jenkins (2005)	n = 34, MF Age 58 ± 9 BMI 27 ± 3	4 wk	1. Vegan: Portfolio 2. NCEP Step 2	0%	0%	↓22%*	↓8%	↓30%*	↓9%	↓7%	↓10%	↓9%*	0%
Barnard (2005)	n = 59, F Age 56	14 wk	1. Vegan 2. NCEP	↓6%*	↓4%	—	—	—	—	—	—	—	—

	BMI 33		Step 2										
Jenkins (2011)	n = 244, MF Age 57 BMI 27	24 wk	1. Vegan: Portfolio 2. NCEP Step 2	↓3%	↓2%	↓10%*	↓1%	↓13%*	↓3%	0%	0%	↓1%	↑4 %
Turner-McGrievy (2007)	n = 59, F Age 56 BMI 33	104 wk	1. Vegan 2. NCEP Step 2	↓4%*	↓1%	—	—	—	—	—	—	—	—
Nicholson (1999)	n = 11, MF Age 54 Bodyweight 96.8 kg	12 wk	1. Vegan 2. ADA	↓7%*	↓4%	↓12%	↓11%	—	—	↓17%*	↓2%	↓12%	↓19 %
Barnard (2006)	n = 99, MF Age 56 BMI 35	22 wk	1. Vegan 2. ADA + CR	↓6%*†	↓3% †	↓18%*‡	↓10% ‡	↓21%*‡	↓9%‡	↓11%‡	↓6%‡	↓16%‡	↓14 %‡
Barnard (2009)	n = 99, MF Age 56 BMI 35	74 wk	1. Vegan 2. ADA + CR	↓5%	↓3%	↓11%*§	↓3%§	↓13%*§	↓3%§	↓2%§	↓1%§	↓19%§	0% §
			Mean change:	↓3%	↓2%	↓18%	↓7%	↓25%	↓7%	↓8%	↓5%	↓10%	↓4 %

ADA: American Diabetes Association diet, BMI: Body mass index (kg/m^2), Conv.: Conventional diet (i.e. NCEP or ADA diet), CR: Calorie restriction, F: Female, M: Male, NCEP: National Cholesterol Education Program diet.

* Post-treatment values significantly different ($P < 0.05$) from baseline values between the intervention groups.

† Among individuals whose diabetes medication usage did not change.

‡ Among individuals whose lipid-controlling medication usage did not change.

§ Change from baseline to end of study or last available value before change in medication usage.

Table 2.

Vegan diets versus conventional diets: Effect on cardiovascular disease risk factors

Reference	Subjects	Trial length	Intervention groups	Systolic BP Change (%)		Diastolic BP Change (%)		Apolipoprotein A1 Change (%)		Apolipoprotein B Change (%)		Apo B:A1 Change (%)	
				Vegan	Conv.	Vegan	Conv.	Vegan	Conv.	Vegan	Conv.	Vegan	Conv.
Jenkins (2001)	n = 10, MF Age 38 ± 4 BMI 25 ± 1	2 wk	1. Vegan: Portfolio 2. NCEP Step 2	↓3%	↓7%	↓4%	0%	↓8%	↓2%	↓26% *	↓6%	↓19% *	↓4%
Jenkins (2003a)	n = 25, MF Age 60 ± 10 y BMI 27 ± 3	4 wk	1. Vegan: Portfolio 2. NCEP Step 2	↓5%	↓6%	↑4%	↓4%	↓7%	↓6%	↓27% *	↓8%	↓22% *	↓2%
Jenkins (2003b)	n = 46, MF Age 59 ± 1 BMI 28 ± 1	4 wk	1. Vegan: Portfolio 2. NCEP Step 2	↓5%	↓6%	↓7%	↓6%	↓8%	↓6%	↓23% *	↓6%	↓18% *	↑1%
Jenkins (2005)	n = 34, MF Age 58 ± 9 BMI 27 ± 3	4 wk	1. Vegan: Portfolio 2. NCEP Step 2	↓4%	↓3%	↓6%	↓3%	↓7%	↓8%	↓24% *	↓8%	↓18% *	↑1%
Barnard (2005)	n = 59, F Age 56 BMI 33	14 wk	1. Vegan 2. NCEP Step 2	—	—	—	—	—	—	—	—	—	—

Jenkins (2011)	n = 244, MF Age 57 BMI 27	24 wk	1. Vegan: Portfolio 2. NCEP Step 2	↓1%	0%	↓2%	0%	↓1%	0%	↓11% *	0%	—	—
Turner-McGrievy (2007)	n = 59, F Age 56 BMI 33	104 wk	1. Vegan 2. NCEP Step 2	—	—	—	—	—	—	—	—	—	—
Nicholson (1999)	n = 11, MF Age 54 Bodyweight 96.8 kg	12 wk	1. Vegan 2. ADA	↓8%	↓13%	↓7%	↓12%	—	—	—	—	—	—
Barnard (2006)	n = 99, MF Age 56 BMI 35	22 wk	1. Vegan 2. ADA + CR	↓3%	↓3%	↓7%	↓4%	—	—	—	—	—	—
Barnard (2009)	n = 99, MF Age 56 BMI 35	74 wk	1. Vegan 2. ADA + CR	0%†	↓1%†	↓4%†	↓3%†	—	—	—	—	—	—
			Mean change:	↓4%	↓4%	↓4%	↓4%	↓6%	↓4%	↓22%	↓6%	↓20%	↓1%

ADA: American Diabetes Association diet, BMI: Body mass index (kg/m^2), BP: Blood pressure, Conv.: Conventional diet (i.e. NCEP or ADA diet), CR: Calorie restriction, F: Female, M: Male, NCEP: National Cholesterol Education Program diet.

* Post-treatment values significantly different ($P < 0.05$) from baseline values between the intervention groups.

† Change from baseline to end of study or last available value before change in medication usage.

Table 3.

Vegan diets versus conventional diets: Effects on glucoregulatory factors

Reference	Subjects	Trial length	Intervention groups	Glucose Change (%)		Insulin Change (%)		Hemoglobin A1C Change (%)		CRP Change (%)	
				Vegan	Conv.	Vegan	Conv.	Vegan	Conv.	Vegan	Conv.
Jenkins (2001)	n = 10, MF Age 38 ± 4 BMI 25 ± 1	2 wk	1. Vegan: Portfolio 2. NCEP Step 2	—	—	—	—	—	—	—	—
Jenkins (2003a)	n = 25, MF Age 60 ± 10 y BMI 27 ± 3	4 wk	1. Vegan: Portfolio 2. NCEP Step 2	—	—	—	—	—	—	—	—
Jenkins (2003b)	n = 46, MF Age 59 ± 1 BMI 28 ± 1	4 wk	1. Vegan: Portfolio 2. NCEP Step 2	—	—	—	—	—	—	↓28%*	↓10%
Jenkins (2005)	n = 34, MF Age 58 ± 9 BMI 27 ± 3	4 wk	1. Vegan: Portfolio 2. NCEP Step 2	—	—	—	—	—	—	↓24%*	↑15%
Barnard	n = 59, F	14 wk	1. Vegan	↓7%	↓2%	↓17%	↓11%	—	—	—	—

(2005)	Age 56 BMI 33		2. NCEP Step 2								
Jenkins (2011)	n = 244, MF Age 57 BMI 27	24 wk	1. Vegan: Portfolio 2. NCEP Step 2	—	—	—	—	—	—	↓13%	↑33%
Turner-McGrievy (2007)	n = 59, F Age 56 BMI 33	104 wk	1. Vegan 2. NCEP Step 2	—	—	—	—	—	—	—	—
Nicholson, (1999)	n = 11, MF Age 54 Bodyweight 96.8 kg	12 wk	1. Vegan 2. ADA	↓28%*	↓12%	—	—	↓17%	↓13%	—	—
Barnard (2006)	n = 99, MF Age 56 BMI 35	22 wk	1. Vegan 2. ADA + CR	↓28%†	↓18%†	—	—	↓15%*†	↓5%†	—	—
Barnard (2009)	n = 99, MF Age 56 BMI 35	74 wk	1. Vegan 2. ADA + CR	↓12%	↓9%	—	—	↓4%	↓2%	↓41%	↓35%
			Mean change:	↓17%	↓11%	↓17%	↓11%	↓11%	↓8%	↓27%	↑1%

ADA: American Diabetes Association diet, BMI: Body mass index (kg/m^2), Conv.: Conventional diet (i.e. NCEP or ADA diet), CR: Calorie restriction, CRP: C-reactive protein, F: Female, M: Male, NCEP: National Cholesterol Education Program diet.

* Post-treatment values significantly different ($P < 0.05$) from baseline values between the intervention groups.

† Among individuals whose diabetes medication usage did not change.

