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Review

A Comprehensive Review of the Literature Supporting Recommendations From the Canadian Diabetes Association for the Use of a Plant-Based Diet for Management of Type 2 Diabetes

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ABSTRACT

Type 2 diabetes mellitus is considered one of the fastest growing diseases in Canada, representing a serious public health concern. Thus, clinicians have begun targeting modifiable risk factors to manage type 2 diabetes, including dietary patterns such as a plant-based diets (PBDs). The Canadian Diabetes Association has included PBDs among the recommended dietary patterns to be used in medical nutrition therapy for persons with type 2 diabetes.

To support knowledge translation, this review summarizes the current literature relating to PBDs and the prevalence of type 2 diabetes, its clinical applications and its acceptability in the management of type 2 diabetes as well as its application in community settings.

This comprehensive review seeks to close the literature gap by providing background and rationale to support the use of PBDs as medical nutrition therapy. Within this review is support from large observational studies, which have shown that PBDs were associated with lower prevalence of type 2 diabetes. As well, intervention studies have shown that PBDs were just as effective, if not more effective, than other diabetes diets in improving body weight, cardiovascular risk factors, insulin sensitivity, glycated hemoglobin levels, oxidative stress markers and renovascular markers. Furthermore, patient acceptability was comparable to other diabetes diets, and PBDs reduced the need for diabetes medications.

Diabetes education centres in Canada could improve patients' perceptions of PBDs by developing PBD-focused education and support as well as providing individualized counselling sessions addressing barriers to change. The development of more standardized and user-friendly PBD practice guidelines could overcome the disparity in recommendations and, thereby, increase how frequently practitioners recommend PBDs. Based on current published research, PBDs lend support in the management of type 2 diabetes.

Mots clés :
lignes directrices de pratique clinique
diabète
prise en charge nutritionnelle
régime alimentaire à base de végétaux

RÉSUMÉ

Le diabète sucré de type 2 est considéré comme étant l'une des maladies à connaître la croissance la plus rapide au Canada et constitue une préoccupation sérieuse de santé publique. Par conséquent, les cliniciens ont commencé à déterminer les facteurs de risque modifiables pour prendre en charge le diabète de type 2, dont les modèles de consommation alimentaire tels que les régimes alimentaires à base de végétaux (RABV). L'Association canadienne du diabète a intégré les RABV aux modèles de consommation alimentaire à utiliser lors de la thérapie nutritionnelle médicale des personnes souffrant du diabète de type 2.

Afin de soutenir le transfert des connaissances, la présente revue résume la littérature actuelle sur les RABV et la prévalence du diabète de type 2, leurs applications cliniques et leur acceptabilité dans la prise en charge du diabète de type 2 ainsi que leur application dans les milieux communautaires.

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Cette revue exhaustive cherche à combler les lacunes de la littérature en fournissant le contexte et les raisons pour appuyer l'utilisation des RABV comme thérapie nutritionnelle médicale. Cette revue s'appuie sur de vastes études observationnelles qui ont montré que les RABV étaient associés à une prévalence plus faible du diabète de type 2. Aussi, les études d'intervention ont montré que les RABV étaient tout aussi efficaces, sinon plus, que les autres régimes alimentaires destinés aux personnes diabétiques pour améliorer le poids corporel, les facteurs de risque cardiovasculaire, l'insulinosensibilité, les concentrations d'hémoglobine glyquée, les marqueurs du stress oxydatif et les marqueurs rénovasculaires. De plus, les RABV dont l'acceptabilité par les patients se comparait à celle des autres régimes alimentaires destinés aux personnes diabétiques réduisaient les besoins en médicaments contre le diabète.

Les centres d'enseignement sur le diabète du Canada pourraient améliorer la perception des patients au sujet des RABV en développant l'enseignement axé sur les RABV et le soutien ainsi qu'en offrant des séances de counseling individuel pour surmonter les obstacles au changement. L'élaboration de lignes directrices de pratique en matière de RABV plus standardisées et faciles à utiliser pourrait surmonter les disparités des recommandations et, ainsi, augmenter la fréquence à laquelle les praticiens recommandent les RABV. Reposant sur la publication de recherche actuelle, les RABV apportent un soutien à la prise en charge du diabète de type 2.

Introduction

Plant-based diets (PBDs) have received increasing interest for their use in the management of various chronic diseases, including cancer, cardiovascular disease, obesity, hypertension and type 2 diabetes mellitus (1,2). A PBD is defined as "a regimen that encourages whole, plant-based foods and discourages meats, dairy products and eggs as well as all refined and processed foods" (3). Type 2 diabetes is considered 1 of the fastest growing diseases in Canada, with more than 60 000 new cases each year (4), and it has become a focal point of clinicians to target modifiable risk factors, such as diet, as a method of preventing and managing type 2 diabetes (1,2).

Dietitians in Canada have stated that vegetarian and vegan diets are nutritionally adequate and, when appropriately planned, can meet the guidelines for the management of type 2 diabetes (5). The Canadian Diabetes Association (CDA) has acknowledged these diets as appropriate in medical nutrition therapy for persons with type 2 diabetes (6). Previous reviews that have summarized the numerous observational studies on PBDs and type 2 diabetes management have not fully explored randomized controlled trials (RCTs) involving PBDs in type 2 diabetes management. Clinical practice guidelines (CPGs) have not provided in-depth quantitative data describing its effectiveness, nor have they mentioned its acceptability and application outside of experimental settings. Moreover, current research has not fully addressed how patients' and clinicians' perceptions could deter its use in clinics outside of experimental settings. Therefore, we sought to summarize the current literature relating to PBDs and the prevalence of type 2 diabetes, along with their experimental applications and acceptability in type 2 diabetes management, as well as their application in community settings, for the purposes of knowledge translation, specifically to researchers and practitioners in Canada.

Methods

Searches of PubMed, ProQuest and Google Scholar were conducted for scientific articles published through March 31, 2015. The following search terms were used: *plant-based diet*, *vegetarian*, *vegan*, *diabetes mellitus* and *type 2 diabetes mellitus*. The search was limited to human studies published in English. Reference lists of all relevant studies as well as relevant systematic reviews, meta-analyses and reviews were examined for further studies. The following criteria were used for study inclusion: studies involving participants with type 2 diabetes who were following PBDs and studies involving PBDs with outcome variables relevant to type 2 diabetes management or risk, including glycated hemoglobin (A1C) levels, fasting blood glucose levels, etc. PBDs included both vegan and vegetarian diets. Figure 1 provides an overview of the comprehensive research strategy and the reasons for exclusions employed in this literature review.

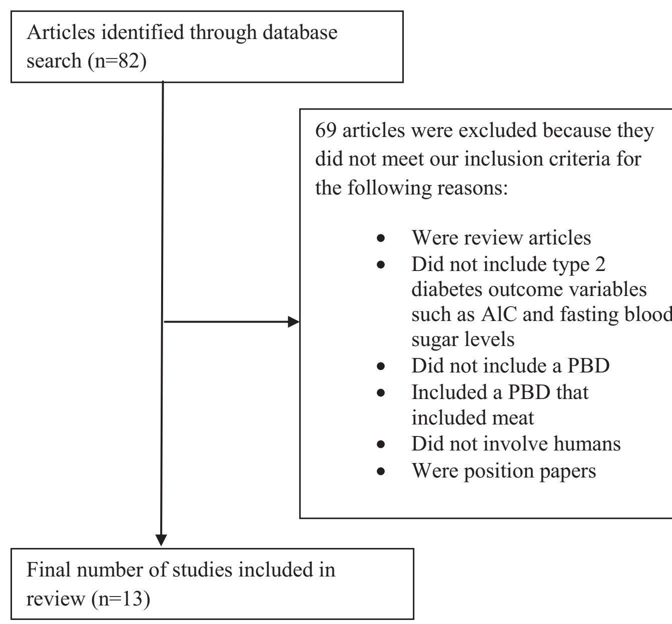

Figure 1. Research strategy algorithm.

Discussion

Prevalence and incidence of type 2 diabetes

Observational studies have shown that the prevalence of type 2 diabetes is lower among individuals who consume PBDs (7,8). A majority of this evidence comes from a long-term observational study investigating the effects of lifestyle and dietary behaviours on disease and mortality in a large sample (N=60 904) of Seventh Day Adventists in Canada and the United States. This population's low incidence of confounding variables (alcohol consumption, smoking and illicit drug use) provides valuable insight into the true associations between diet and diabetes (7).

Initially, cross-sectional analyses of the cohorts' baseline data were conducted (7). In logistic regression analysis, compared with nonvegetarians, the multivariate adjusted odds ratios for type 2 diabetes prevalence increased incrementally based on the dietary patterns: vegan (OR 0.51; 95% CI: 0.40 to 0.66); lacto-ovovegetarian (OR 0.54; 95% CI: 0.49 to 0.60); pescovegetarian (OR 0.70; 95% CI: 0.61 to 0.80) and semivegetarian (OR 0.76; 95% CI: 0.65 to 0.90). Body mass indexes (BMIs) followed a similar trend, with the lowest indexes observed in vegetarians and the highest in nonvegetarians ($p<0.0001$).

Follow-up analyses of the participants without reported diabetes at baseline were conducted at 2 years (8). In multivariate logistic regression analyses, the odds ratios for developing diabetes compared with nonvegetarians increased incrementally in the following order: vegan (OR 0.38; 95% CI: 0.24 to 0.62); semivegetarian (OR 0.49; 95% CI: 0.31 to 0.76); lacto-ovovegetarian (OR 0.62; 95% CI: 0.50 to 0.76) and pescovegetarian (OR 0.79; 95% CI: 0.58 to 1.09). Taken together, these data suggest that PBDs offer a protective effect against type 2 diabetes.

Similar results were found in a prospective cohort study of 8401 vegetarians and nonvegetarians from 2 original studies involving Adventist church members in California who did not report diabetes at baseline (9). The 17-year follow-up indicated that weekly consumers of all types of meats were more likely to develop diabetes compared to those consuming no meat (1.29 OR; 95% CI: 1.08 to 1.55) (9). Additionally, those who consumed processed meats were more likely to develop diabetes than those who did not (1.38 OR; 95% CI: 1.05 to 1.82) (9). Adherence to a diet that included at least weekly meat consumption over a 17-year period was associated with an increase in the odds of developing diabetes relative to long-term adherence to a vegetarian diet (1.74 OR; 95% CI: 1.36 to 2.22).

An RCT by De Mello et al explored red-meat consumption as a risk factor for type 2 diabetes (10). Three isoenergetic diets were utilized: participants' usual diets (UDs), a chicken diet (CD) in which red meat was replaced with chicken meat; and a lactovegetarian low-protein diet (LPD). Although changes in fasting plasma glucose were not significant among those consuming the diets, the CDs and LPDs resulted in improvements in lipid profiles. Non-high-density lipoprotein (HDL) cholesterol levels decreased significantly in those following the CDs and LPDs compared with the UD (3.92±0.99 mmol/L, 3.92±0.93 mmol/L; 4.23±1.06 mmol/L; $p<0.05$), while triacylglycerols decreased significantly in those consuming the CD compared to the UD (1.22 mmol/L; 1.46 mmol/L; $p<0.05$). Significant reductions in urinary albumin excretion rate, a renovascular risk factor, were observed with the CDs and LPDs compared to the UD (269.4 μg/min, 229.3 μg/min; 312.8 μg/min; $p<0.05$). Taken together, the results of these studies suggest that meat quality is a risk factor for the development of type 2 diabetes and is also an important factor in the management of its comorbidities.

A randomized cross-sectional study by Yang et al offered insight into the mechanisms by which a PBD could account for lower prevalence of type 2 diabetes by investigating whether it had a protective effect on metabolic diseases (11). We recruited 295 healthy Chinese men older than 20 years of age and assessed their anthropometric indexes, lipid profiles, insulin sensitivities and pancreatic beta-cell functions. A self-administered questionnaire assessed their dietary patterns, which identified 169 participants following a lactovegetarian diet and 126 following an omnivorous diet.

The authors reported that healthy lactovegetarian men had significantly lower levels of fasting blood glucose (4.72 mmol/L±0.68; 5.06 mmol/L±0.69; $p<0.001$) and statistically significant greater insulin secretion indexes, a measure of beta-cell function (1.60±1.06; 1.39±0.70′ $p=0.48$) than healthy omnivorous men (11). Furthermore, gamma-glutamyltransferase (gamma-GT) was significantly lower in vegetarians than in omnivores (21.87 IU/L±18.09; 31.02 IU/L±18.05; $p<0.001$). Gamma-GT is highly related to oxidative stress, which plays important roles in both metabolic diseases and cardiovascular disease (11). Raised gamma-GT has been considered a significant independent predictor of impaired glucose tolerance and diabetes mellitus (11). These studies lay the foundation for experimental research that investigates the effectiveness of PBDs as compared to other healthful non-PBDs for the management of type 2 diabetes.

Management of type 2 diabetes

In an RCT, Nicholson et al investigated PBDs' effects on outcomes in persons with type 2 diabetes in the absence of exercise intervention (12). They randomized 11 participants with type 2 diabetes into 2 groups: 1 group followed a low-fat vegan diet, and the other group followed a conventional low-fat diet; they were required to follow their respective diets for 12 weeks. A significantly greater reduction in fasting serum glucose levels (28%, 12%; $p<0.05$) and body weights (7.2 kg, 3.8 kg; $p<0.005$) were observed in the vegan group compared to the conventional diet group (12). Oral hypoglycemia medication was discontinued in 1 participant and reduced in 3 participants in the vegan group, but no changes in glycemic control in participants in the conventional diet group warranted medication reductions (12). The participants in the vegan group had significantly greater reductions in HDL cholesterol (0.2 mmol/L, 0.02 mmol/L; $p<0.05$) than those in the conventional diet group (12). Although commonly observed in low-fat vegetarian diets, reductions in HDL levels have been reported as having no association with increased atherosclerotic risk in the context of low total cholesterol (12). The results of this study are unique in that they were the first to observe that PBDs, independent of exercise interventions, have the potential to produce greater beneficial changes in fasting serum glucose levels and body weight, despite the confounding effects of reduced medication use. Although novel, the results are limited by the small sample size.

Additionally, it has been suggested that a PBD is associated with greater insulin sensitivity and reductions in body weight (13). A large 74-week RCT conducted by Barnard et al was designed to compare the efficacy of a vegan diet to a conventional diabetes diet in adults with type 2 diabetes treated with antihyperglycemic agents for at least 6 months (14). Participants were screened to exclude individuals with A1C levels <6.5% and >10.5%; those who had used insulin for >5 years; those who regularly used tobacco, alcohol or illicit drugs; those who had unstable medical statuses and those on low-fat vegetarian diets at the time of the study.

Participants were randomly assigned to either a vegan diet ($n=49$) or a conventional diet ($n=50$) based on the 2003 American Diabetes Association (ADA) guidelines. Portion sizes, energy intake and carbohydrate intake were not restricted, although participants in the experimental group were encouraged to choose low glycemic-index foods and were instructed to avoid animal products and fatty foods. The vegan diet provided 10% of total energy from fat, 15% from protein and 75% from carbohydrates. The ADA control group consumed a diet providing 15% to 20% of total energy from protein, <7% from saturated fat and 60% to 70% from carbohydrates and monounsaturated fats. Participants in the ADA group were restricted to fewer than 200 mg per day of cholesterol, and participants with BMIs >25 kg/m^2 were prescribed a daily 500 to 1000 kcal deficit.

A registered dietitian met with each participant for 1 hour to establish an appropriate diet plan. For 22 weeks, participants were required to attend weekly 1-hour meetings specific to their assigned groups for nutrition and cooking instruction. Participants had the option of attending these meetings biweekly for the remainder of the protocol. Three-day food records to estimate nutrient intakes, dietary acceptability and compliance were recorded at baseline and at 11, 22 and 74 weeks. Additionally, a registered dietitian conducted 24-hour recalls at weeks 4, 8, 13, 20, 33, 45 and 60 and identified dietary nonadherence.

Although both groups reported reduced intakes of total fat, saturated fat and cholesterol, these reductions were significantly greater in the vegan group at 74 weeks ($p<0.0001$) (14). The vegan group reported significantly greater intakes of carbohydrates and dietary fibre at 74 weeks ($p<0.0001$) (14). Both groups' diets resulted in significant weight loss from baseline (vegan: 4.4 kg; $p<0.0001$; control: 3 kg; $p<0.001$), although there was no significant difference in mean weight loss in the groups at 74 weeks (14). Intergroup reductions in urinary albumin were significant when adjusted for baseline values, with greater reductions observed in the experimental group than in the conventional diet group (–8.88 μg/min; 10.14 μg/min; $p=0.05$). The mean change in A1C levels was slightly greater in the vegan group than in the control group (0.34% vs. 0.14%), although intergroup differences did not meet significance. Both diets resulted in significant improvements in plasma lipid profiles, but between-group comparisons did not meet significance.

Diabetes medications were adjusted during the study as glycemic control improved. Participants in the vegan-diet group were more likely to see reductions in antihyperglycemic medications than those in the conventional-diet group. These reductions could have confounded the study's results, so the authors completed an additional analysis of the data before medication adjustments. The analysis showed that there were significantly greater reductions in A1C levels (–0.4% vs. +0.01%; $p=0.03$); total cholesterol levels (–0.53 mmol/L; –0.18 mmol/L; $p=0.01$); LDL-cholesterol (–0.35 mmol/L; –0.09 mmol/L; $p=0.03$) and non-HDL-cholesterol (–0.50 mmol/L; –0.16 mmol/L; $p=0.02$) in the vegan group compared to the ADA diet group.

The results of this study provide evidence to suggest PBDs offer more benefits when used in the management of type 2 diabetes than do conventional ADA diets. The long-term duration, as well as the inclusion of persons with long-standing diabetes, strengthen the results of the study. Medication changes typically present a challenge in long-term studies involving diabetes outpatients. The results of this study are limited by the free-living nature of the participants who were not provided with meals specific to their assigned groups. Despite these limitations, the analysis results revealed greater A1C-lowering effects and greater weight loss in the vegan diet group, which provides support for PBDs.

To investigate the possible mechanisms explaining the results of the previous studies, Kahleova et al conducted an RCT to compare the effects of vegetarian and conventional diabetes diets on insulin resistance, visceral fat and plasma markers of oxidative stress after a 3-month dietary-intervention (13). The study included 74 participants between 30 and 70 years of age with type 2 diabetes who were being treated with oral hypoglycemic drugs, had A1C levels between 6% and 11% and BMIs between 25 and 53, and were willing to alter their dietary habits while following a prescribed exercise program.

The subjects were randomly assigned to either an experimental group following a vegetarian diet ($n=37$) or a control group following a conventional diabetes diet ($n=37$). Both diets were designed to be isoenergetic, providing a reduction of 500 kcal per day. The vegetarian diet (60% total energy from carbohydrates, 15% from protein, 25% from fat) limited the consumption of animal products to 1 portion of low-fat yogurt per day. The conventional diet followed the guidelines of the Diabetes and Nutrition Study Group of the European Association for the Study of Diabetes (50% total energy from carbohydrates, 20% from protein, <30% from fat [<7% saturated fat, <200 mg cholesterol]). Both groups were provided with all their meals plus vitamin B_{12} supplements, and they received weekly 1-hour meetings with lectures and cooking classes. At 12 weeks, both groups were required to begin an aerobic exercise protocol.

At the conclusion of the study, the results indicated that 55% of the participants in the experimental group reported high dietary adherence, compared to 32% in the control group. No significant between-group differences were observed in pedometer readings and self-reported energy expenditures, suggesting that the effects of exercise were similar in both groups. As observed in previous studies, participants following the vegetarian diet reduced their use of diabetes medication significantly more than those in the control group (43% vs. 5%; $p<0.001$). Only the experimental group had significantly reduced their A1C levels at 24 weeks (–0.65%±0.99; $p<0.001$); however, between-group differences did not meet significance. After controlling for medication changes, participants in the experimental group had significantly reduced their A1C levels by 0.9% ($p=0.002$) compared to a nonsignificant 0.2% reduction in the control group, although between-group differences did not meet significance ($p=0.08$) (14). At 24 weeks, weight loss (6.2 kg, 3.2 kg; $p=0.001$) and the reduction in waist circumference (–6.4 cm; 95% CI: –7.1 to –5.7); –5.3 cm; 95% CI: –5.9 to –4.5; $p=0.001$); visceral fat ($p=0.007$) and subcutaneous fat ($p=0.02$) were significantly greater in the experimental group than in the control group. There was a significantly greater increase in insulin sensitivity in the experimental group than in the control group (30% vs. 20%; $p=0.04$) (13). Experimental group participants' plasma adipokines adiponection and leptin significantly increased (19%; 95% CI: 7.5 to 25.4; $p=0.02$) and decreased (35%; 95% CI: –43 to –21.6; $p=0.05$), respectively, whereas no changes were observed in the control group. The experimental group had statistically significant greater improvements in the oxidative stress markers: plasma vitamin C (16%; 95% CI: 13.5 to 24.7; $p=0.002$); superoxide dismutase (49%; 95% CI: 44.7 to 57.4; $p<0.001$); reduced glutathione (27%; 95% CI: 16.8 to 29.6; $p<0.001$), whereas the control group did not (13).

The authors suggested that the loss of visceral fat and its consequent increase in insulin sensitivity could account for the PBDs' advantageous effects (13). Reductions in intramyocellular lipid concentrations that have been observed in persons following vegetarian diets in conjunction with this reduction in visceral fat could be responsible for a large portion of the effects on insulin sensitivity and oxidative stress markers (13). The authors provided several possible mechanisms to explain these beneficial effects, including higher intakes of fibre, lower intakes of saturated fat, higher intakes of nonheme iron and reduction in iron stores, higher intakes of vegetable protein in the place of animal protein, or higher intakes of antioxidants and plant sterols.

The number of participants included in the study did not provide sufficient power to observe statistically significant between-group differences in A1C reduction and, thereby, could not confirm the previously observed superior effect PBDs have on A1C levels (13). Barnard et al showed that persons following an ad libitum PBD experience weight reductions similar to those of persons consuming energy restricted diabetes diets (14), providing support to the proposed mechanism in which the high-fibre and low-fat composition of PBDs result in weight loss. The inclusion of energy restrictions in the PBDs used in this study design could account for the statistically significant greater weight reduction observed in the experimental group compared to the control group.

A recent meta-analysis of 6 control trials, discussed in this review, investigated the association between PBDs and changes in A1C levels (15). Six studies assessing vegan/vegetarian diets were compared to conventional omnivorous diets. Pooled analysis revealed a significant reduction in mean A1C levels (–0.39%; 95% CI: –0.62 to –0.15; $p=0.001$; $I^2=3.0$; p for heterogeneity=0.389) in the intervention diets vs. the control diets (15). The results of this meta-analysis provide encouraging evidence of the effectiveness of PBDs in type 2 diabetes management because when compared to the effectiveness of diabetes medications, the reduction in A1C levels via PBD intervention was approximately half of the 0.9% reduction observed in response to metformin intervention (15).

There is, therefore, sufficient evidence to support the use of PBDs in medical nutrition therapy for the treatment of type 2 diabetes. This is why the new 2013 CDA CPGs recommend the use of PBDs among 3 other dietary patterns for the management of type 2 diabetes, including the Dietary Approaches to Stop Hypertension diet, the Mediterranean diet and diets high in dietary pulses (6). However, larger clinical trials are needed to understand further the mechanisms by which PBDs produce these effects as well as to compare their effectiveness against the other dietary patterns for the management of type 2 diabetes in Canada.

Acceptability and use in a community setting

In addition to the data concerning the potential effects PBDs have on dietary and metabolic parameters in those with type 2 diabetes, there are data published by Kahleova et al, who measured participant-reported quality of life (measured using the Obesity and Weight Loss Questionnaire and the Weight-Related Symptoms Questionnaire); mood (measured using the Beck Depression Inventory) and eating behaviours (measured using the Three-Factor Eating Questionnaire) at baseline, 12 weeks and 24 weeks (13,16). At the end of the 24-week period, participants following the vegetarian diet significantly increased their quality-of-life scores more than those following the conventional diet ($p=0.01$). At 12 weeks, both groups decreased their depression scores, although the decrease was significant only in the vegetarian group at 24 weeks ($p<0.001$). It is important to note that the mean Beck Depression Inventory scores for each group did not reach the threshold required for diagnoses of depression. There was a statistically significant difference in dietary restraint between the groups, with the control group reporting more restraint ($p=0.04$), whereas only the vegetarian group indicated significant decreases in disinhibition at 24 weeks ($p<0.001$). Collectively, these results suggest that the participants following the conventional diabetes diet felt more constrained by their food choices and that the participants in the vegetarian group were less likely to overeat. The authors concluded that the participants following PBDs had superior improvements in quality of life, mood and eating behaviours, suggesting that the diet could be sustainable in the long term.

Barnard et al (14,17) suggested that the superior improvements in eating behaviours following a PBD (dietary restraint and disinhibition) dissipate over time and are similar to those of persons following conventional diabetes diets after a 74-week intervention (17). Furthermore, at 74 weeks, there were no statistically significant differences in the acceptability, the diet compliance or the food cravings between groups (17). Despite the low-fat vegan diet's greater influence on macronutrient intake, it had acceptability similar to that of a conventional low-fat diabetes diet. Comparing these results with similar studies it is important to consider that there may be inherent differences between vegan and vegetarian diets despite both being PBDs.

Ferdowsian et al conducted a study to observe whether the reported improvements in body weight and glycemic control in overweight persons following PBDs could be replicated in a workplace setting (18). Participants (with or without type 2 diabetes) were recruited to either an intervention group consuming a low-fat vegan diet ($n=65$) or a control group consuming a regular diet ($n=45$). The intervention group was required to attend group meetings involving dietary support and cooking instructions and were provided with low-fat vegan options in their cafeteria daily.

At 22 weeks, the results indicated that a PBD had a superior effect on weight loss (–5.3 kg; 95% CI: –7.0 to –3.5; $p<0.0001$) in all participants. After 22 weeks, the results indicated that when controlling for medication changes, participants with type 2 diabetes who had been consuming a PBD had decreased their A1C levels by 1.0% ($n=5$) compared to a 0.2% reduction ($n=6$) in those without dietary changes. While this indicates a significant effect on A1C levels, it is limited in its reliability because the sample sizes were too small for statistical analyses.

Mishra et al provided additional evidence to support this observation after conducting a 10-site, workplace-based RCT on individuals previously diagnosed with type 2 diabetes and BMIs ≥ 25 m/kg^2 (19). Participants were randomized to either a low-fat vegan diet group with no energy restrictions or to a control group that was required to make no dietary changes for 18 weeks. The intervention group was required to avoid animal products and were urged to use added oils minimally but to favour low glycemic-index foods. Participants in the intervention group also received weekly group support, suitable cafeteria options and vitamin B_{12} supplementation. Total fat ($p<0.001$), saturated fat ($p<0.001$) and protein ($p<0.001$) intakes were significantly lower in the intervention group compared to the control group, and dietary fibre consumption ($p=0.001$) was significantly greater at the conclusion of the study (19). There were also greater improvements in body weight (–2.9 kg; –0.06 kg; $p<0.01$); total cholesterol (–0.44 mmol/L; –0.0006 mmol/L; $p<0.001$), LDL cholesterol (–0.45 mmol/L; –0.05 mmol/L; $p<0.001$) and A1C levels (–0.6%; –0.08%; $p=0.004$) in the intervention group compared to the control group. These results were expected because the control group did not make any dietary changes. It is important to note that the changes in body weight, A1C, total cholesterol and LDL cholesterol levels were similar to the changes observed in the clinical studies of longer duration (14) despite their differing study designs (19). This study does suggest that the superior benefits of consuming a PBD hold true in a workplace setting, but the study's results could have been attenuated by the additional social support system provided.

Barriers to usage in Canada

The CDA recommends PBDs, among other dietary patterns, to manage type 2 diabetes, but the diet is "often perceived to be extreme and difficult to follow," according to patients (3). It has been suggested that healthcare providers may influence this perception in patients. An Ontario-based diabetes education centre pilot study assessed awareness, barriers and promoters of PBD use for the management of type 2 diabetes. The study included 98 patients with prediabetes, type 1 diabetes or type 2 diabetes, and 25 healthcare providers. The participants were required to complete 1 of 2 surveys addressing the patients' feelings about PBDs or the professionals' attitudes and current practices concerning PBDs.

The results indicated that 89% of patients were unaware of the opportunity to use an alternative diet, such as a PBD, for the prevention and management of type 2 diabetes (3). Few respondents were confident in their abilities to follow a PBD, although 66% of the patients were willing to follow a PBD for 3 weeks if support were provided. The patients reported that family influence, preference for meat and meal-planning skills were the top 3 barriers to implementing a PBD, and that their main educational needs in order to successfully follow PBDs were a vegetarian education program consisting of individual or group counselling and cooking instructions (3). The development of PBD-specific education and support programs, including individual or group counselling sessions that address barriers to change, may help to increase patient acceptability and efficacy in adopting PBDs.

Results from healthcare providers indicated that a common reason for avoiding the recommending of PBD diets was that they were too difficult to follow and that patients were unlikely to accept them. Additional reasons staff did not recommend PBDs were unclear CPGs and scientific evidence regarding PBDs. Differing vegetarian food guides and practical guidelines available to nutrition professionals may pose challenges to nutrition counselling by creating inconsistent understandings of recommendations. The

Table 1
Summary of recommendations for a plant-based diet (PBD) to improve management of type 2 diabetes

	Clinical practice
1	A PBD is an effective diet in the management of type 2 diabetes because it has been shown to have the following beneficial effects: ○ Improved fasting blood glucose (11) ○ Improvements in A1C levels (13–15,19) ○ Oral hypoglycemic medication discontinuation (12) ○ Improvements in body mass index (BMI) (7), body weight (12,19) and waist circumference (14) ○ Reduction in total cholesterol (14,19) ○ Decreased low-density lipoprotein (LDL) cholesterol (14,19) ○ Decreased non-HDL cholesterol (10,14) ○ Increased quality of life scores and decreased depression (17)
2	Practitioner and patient education is key to improve both clinicians' confidence in recommending PBDs and patients' abilities to adopt PBD diets; this may be done through standardized PBD-specific practice guidelines.
3	Appropriate education and counselling are necessary to ensure that it is appropriately planned to prevent potential nutrient deficiencies associated with avoidance of meat, such as insufficient calcium, vitamin D, vitamin B_{12}, protein, iron, riboflavin and zinc (5).
4	In cases where patients are not agreeable to following a strict PBD, it is important to consider patients' preferences and abilities to make other relevant dietary changes. Research has suggested that the type of meat may be more important than the quantity of meat consumed in the development of type 2 diabetes and that there may be varying benefits between different types of vegetarian and vegan diets. Thus, an effective goal may be to make progressive diet modifications for patients, such as consuming less processed meat or reducing meat intake so as to shift patients' diets closer to rather than completely to PBDs.
5	Initial and ongoing support for patients is important for the adoption and maintenance of PBDs.
	Future research
1	Long-term randomized controlled trials (RCTs) involving participant follow up should be conducted to study the long-term benefits of PBDs in patients with type 2 diabetes.
2	It is recommended that future studies examine the effects of other accepted diets for type 2 diabetes management and compare their effects to a restrictive vegan diet.
3	Additional studies representative of the diverse Canadian population with type 2 diabetes and involving the clinicians caring for these patients are necessary.

development of more standardized and user-friendly practice guidelines concerning PBDs could overcome this discrepancy and, thereby, increase the number of practitioners who recommend PBDs to patients with type 2 diabetes. It is also possible that a lagtime in the dissemination of PBD information from research to clinician and finally to patient could explain why diabetes education centre staff were reluctant to recommend PBDs. Thus, this review can act as a comprehensive tool to facilitate the dissemination to clinicians of research findings concerning PBDs.

This study does provide valuable insight into the barriers to implementing PBDs, but the small sample size and recruitment design limit the applicability and generalizability of the results to the rest of Canada. Additionally, because of the absence of validated questionnaires for use in the subject area, the survey instruments were not validated, thereby limiting the ability to compare the results to other studies. Therefore, additional research from various geographic areas across Canada involving patients and healthcare providers representative of the whole Canadian population are required before recommending PBD-specific education programs and changing Canadian CPGs.

To our knowledge, no long-term RCTs have been conducted that study the long-term benefits of PBDs in patients with type 2 diabetes, so future research should include longer follow up of participants. Moreover, a majority of the trials used a restrictive vegan diet, which may be unsuitable for some patients with type 2 diabetes. We recommend that further studies examine differences in effectiveness and acceptability between vegan and vegetarian diets for the management of type 2 diabetes and compare PBDs to the other recommended dietary patterns for the management of type 2 diabetes in Canada. Additionally, future studies should include populations that are reflective of the diverse Canadian population with type 2 diabetes, specifically, the populations that indicate greater prevalence so as to determine whether these benefits still occur.

Conclusions

The current Canadian CPGs recommend PBDs for the management of type 2 diabetes because of their potential to improve body weight and A1C, LDL-cholesterol, total cholesterol and non-HDL-cholesterol levels, in addition to reducing the need for diabetes medications. Building on the background outlined herein and in the spirit of the contributions from CPGs, this review complements those guidelines and provides further evidence of the acceptability and buy-in of PBDs from patients' perspectives. As well, addressing how patients' and clinicians' perceptions or attitudes affect their use in clinical settings, along with the many metabolic improvements, lend support to the beneficial effects of PBDs. However, although there are many promising results of adhering to a strict PBD nutrition-care plan regarding type 2 diabetes management, clinicians should be aware that not all patients may choose to follow this type of diet plan. It is important for clinicians to be aware that some positive benefits can still occur through diet modifications that include fewer processed meats or to move closer on the spectrum to a complete PBD. With any PBD, clinicians should ensure that the diet is appropriately planned to prevent the potential nutrient deficiencies associated with avoidance of animal products, such as insufficient calcium, vitamin D, vitamin B_{12}, protein, iron, riboflavin and zinc (5).

To help facilitate knowledge translation, it would be beneficial to develop initiatives that promote the benefits and acceptability of PBDs in the management of type 2 diabetes as well as to inform clinicians about appropriate prescription of PBDs.

Table 1 outlines recommendations gleaned through this comprehensive review.

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