



# A plant-based diet for overweight and obesity prevention and treatment

Gabrielle Turner-McGrievy, Trisha Mandes, Anthony Crimarco

Department of Health Promotion, Education, and Behavior, Arnold School of Public Health, University of South Carolina, Columbia, USA

## Abstract

The goal of this paper is to review the evidence related to the effect of plant-based dietary patterns on obesity and weight loss, including both observational and intervention trials. Literature from plant-based diets (PBDs) epidemiological and clinical trial research was used to inform this review. In addition, data on dietary quality, adherence, and acceptability were evaluated and are presented. Both clinical trials and observational research indicate an advantage to adoption of PBDs for preventing overweight and obesity and promoting weight loss. PBDs may also confer higher levels of diet quality than are observed with other therapeutic diet approaches, with similar levels of adherence and acceptability. Future studies should utilize health behavior theory to inform intervention development and delivery of PBDs studies and new technologies to bring interventions to scale for greater public health impact. Research examining PBDs and weight loss is also needed with more diverse populations, including older adults. Based on the available evidence, PBDs should be considered a viable option for the treatment and prevention of overweight and obesity.

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## 1 Introduction

More than two-thirds (69%) of U.S. adults are overweight or obese [body mass index (BMI) > 25 kg/m<sup>2</sup>].<sup>[1]</sup> Overweight and obesity are associated with a number of chronic diseases, including type 2 diabetes,<sup>[2]</sup> metabolic syndrome,<sup>[3]</sup> hypertension,<sup>[4,5]</sup> and cardiovascular disease (CVD).<sup>[4,5]</sup> Even modest weight loss—5% decrease in body weight—has been shown to lower the risk of chronic disease.<sup>[6,7]</sup> Diets used in traditional, behavioral weight loss interventions have primarily focused on energy restriction to promote reductions in body weight.<sup>[8]</sup> There is also a growing body of literature examining the use of plant-based diets (PBDs) for weight loss.<sup>[9,10]</sup>

PBDs, including vegan and vegetarian diets, are based around fruits, vegetables, grains, and legumes, with vegetarian diets also typically including dairy products and eggs. This review includes both vegetarian and vegan diets under the umbrella term of PBDs. Definitions of the various diets described in this review, along with sample dinner plans, are

included in Table 1. The goal of this paper is to summarize the evidence related to the effect of plant-based dietary patterns on obesity and weight loss, including the literature from both observational and intervention trials. This article also discusses issues around adherence and acceptability, use of theory to promote behavior change, need for innovative delivery methods in PBDs intervention work, and issues relevant to an older (e.g., ages 65 and older) population.

## 2 Observational studies

Several epidemiological studies have examined differences in body weight based on dietary patterns. These patterns include vegan, vegetarian (veg), pesco-vegetarian (pesco-veg), semi-vegetarian (semi-veg), or omnivorous (omni) diets.<sup>[11]</sup> Data from the Adventist Health Study (AHS) have shown that BMI increases as the amount of animal foods in the diet increases, such that vegans had the lowest BMI, followed by veg, pesco-veg, semi-veg, and omni diets.<sup>[11]</sup> Moreover, findings from the European Prospective Investigation into Cancer and Nutrition (EPIC-Oxford) study, have shown that vegans gain significantly less weight as they age compared to omnivores.<sup>[12]</sup> Converting to a more plant-based diet also appears to be protective against weight gain, as does following a pesco-veg diet for women.<sup>[12]</sup> The EPIC-PANACEA study, an off-shoot of the EPIC-Oxford study, found a positive association between total meat con-

**Correspondence to:** Gabrielle Turner-McGrievy, PhD, Department of Health Promotion, Education, and Behavior, Arnold School of Public Health, University of South Carolina, 915 Greene Street, Room 529 Columbia, SC 29208, USA. E-mail: brie@sc.edu

**Telephone:** +1-803-777-3932 **Fax:** +1-803-777-6290

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**Table 1. Definitions of diet terms and example meals.**

Dietary group	Definitions of diet patterns	Example dinner meal
Vegan diet (vegan)	Does not contain any animal products (meat, fish, poultry, eggs, or dairy) but emphasizes plant-based foods, such as fruits, vegetables, whole grains, and legumes/beans	Black-eyed peas and brown rice with chopped tomatoes and roasted peppers Side salad
Vegetarian diet (veg)	Does not contain meat, fish, or poultry but does contain eggs and dairy, in addition to plant-based foods, such as fruits, vegetables, whole grains, and legumes/beans	Black-eyed peas and brown rice with chopped tomatoes, roasted peppers, and reduced fat cheddar cheese. Side salad
Pesco-vegetarian diet (pesco-veg)	Does not contain meat or poultry but does contain fish and shellfish, eggs, and dairy, in addition to plant-based foods, such as fruits, vegetables, whole grains, and legumes/beans	Black-eyed peas and brown rice with shrimp, chopped tomatoes, roasted peppers, and reduced fat cheddar cheese. Side salad
Semi-vegetarian diet (semi-veg)	Contains all foods, including meat, poultry, fish and shellfish, eggs, and dairy, in addition to plant-based foods, such as fruits, vegetables, whole grains, and legumes/beans. However, red meat and poultry and fairly limited	Black-eyed peas and brown rice with low-fat turkey sausage, chopped tomatoes, roasted peppers, and reduced fat cheddar cheese. Side salad
Omnivorous diet (omni)	Contains all food groups	Black-eyed peas and brown rice with low-fat sausage, chopped tomatoes, roasted peppers, and reduced fat cheddar cheese. Side salad

sumption and weight gain, even after adjusting for energy intake: an increase in 250 g/day of meat led to a 2 kg weight gain after 5 years (95% CI: 1.5–2.7 kg).<sup>[13]</sup>

Along with the findings from the two large AHS and EPIC studies, the Swedish Mammography Cohort found that omnivores had the highest prevalence of overweight and obesity compared to individuals following dietary patterns with less meat.<sup>[14]</sup> In a study examining a cohort of 49,098 Taiwanese adults, the percentage of participants with a BMI  $\geq 27$  kg/m<sup>2</sup> was significantly lower among those following a vegetarian diet (10.9%) as compared to those following a non-vegetarian diet (15.4%). Additionally, this study also found that for every year on a vegan diet, the risk of obesity decreased by 7% (95 % CI: 0.88–0.99).<sup>[15]</sup>

### 3 Intervention studies

Two recent meta-analyses of clinical trials assessing PBDs and weight loss found significant weight loss among participants prescribed a PBDs.<sup>[9,10]</sup> Barnard, *et al.*,<sup>[9]</sup> reviewed 15 clinical trials that used PBDs for at least four weeks without energy intake restrictions. The researchers found that PBDs were associated with a mean weight loss of –3.4 kg in an intention-to-treat analysis and 4.6 kg in a completers-only analysis.<sup>[9]</sup> Their study also found that the participants' age and gender were significantly associated with weight change. Older age was associated with greater weight change in the completer analysis. Studies with a smaller proportion of female participants were also associated with greater weight change in both the intention-to-treat and completer analysis.<sup>[9]</sup>

Huang, *et al.*'s meta-analysis of clinical trials also indi-

cated significant weight loss among individuals assigned to a PBDs.<sup>[10]</sup> Among the 12 studies reviewed, participants randomized to some type of vegetarian diet lost an average of –2.02 kg more than the participants assigned a non-vegetarian diet.<sup>[10]</sup> Six of the 12 studies involved energy restriction; unsurprisingly, the average weight loss was greater among the energy-restricted vegetarian diets than non-energy restricted vegetarian diets (mean of –2.2 kg vs. –1.6 kg, respectively).<sup>[10]</sup> Subgroup analyses indicated that participants in a vegan diet condition lost more weight than participants in a vegetarian diet condition (mean of –2.5 kg vs. –1.5 kg, respectively).<sup>[10]</sup> Additional clinical trials examining the use of PBDs for weight loss have been published since the two meta-analyses discussed here. These include the New DIETs study,<sup>[16]</sup> HER Health Study,<sup>[17]</sup> and the VA BEACH Diet Study,<sup>[18]</sup> all of which reported significant weight loss among individuals prescribed a PBDs.

### 4 Diet quality, adherence, and acceptability of PBDs

#### 4.1 Diet quality

The Academy of Nutrition and Dietetics Position Paper states that vegan and vegetarian diets “are healthful, nutritionally adequate, and may provide health benefits in the prevention and treatment of certain diseases.”<sup>[19]</sup> Use of PBDs for weight loss may confer benefits to improved diet quality not seen with traditional, energy-restricted diet approaches. For example, a 22-week intervention for adults with type 2 diabetes comparing the use of a PBD vs. the American Diabetes Association diet guidelines (ADA diet)

found significantly greater improvements in dietary quality (assessed by the Alternate Healthy Eating Index, AHEI) among the PBDs participants as compared to the ADA diet participants.<sup>[20]</sup> Another study, which analyzed the menu plans of popular weight loss books using the AHEI, found that the Ornish plan—a PBD approach for weight loss—had the highest AHEI score, which was significantly higher than plans using a high-protein diet approach.<sup>[21]</sup>

#### 4.2 Diet adherence

Adherence to PBDs appears to be similar to most other therapeutic dietary approaches. As stated above, two meta-analyses on clinical trials of PBDs and weight loss were recently published, representing 20 unique intervention studies.<sup>[9,10]</sup> Of those 20 studies, 11 reported a measure of dietary adherence (e.g., if participants adhered to their assigned diet). Mean compliance rate of those 11 was 69% for vegan or vegetarian participants and 64% for comparison group participants.<sup>[9,10]</sup> The recently completed (and therefore not included in the two meta-analyses) New DIETs study randomized 63 participants to follow a vegan ( $n = 12$ ), veg ( $n = 13$ ), pesco-veg ( $n = 13$ ), semi-veg ( $n = 13$ ), or omni diet ( $n = 12$ ) for six months.<sup>[16]</sup> Diet compliance was defined as the absence of proscribed foods on two 24-hour recalls at two and six months (e.g., no meat, fish, or poultry on vegetarian participants' recalls). No differences in dietary adherence among the five groups were found at two ( $\chi^2 = 5.2$ ,  $P = 0.27$ ) or six months ( $\chi^2 = 0.47$ ,  $P = 0.98$ ).<sup>[22]</sup> The New DIETs study also examined whether recommendations to consume a PBD still had advantages for weight loss even if dietary compliance was not complete. Examining data among only non-adherent participants, this study found that non-compliant vegan and vegetarian participants ( $n = 16$ ) were still consuming a more plant-based diet at six months than other groups, as evidenced by a significantly greater decrease in animal product intake ( $-190.2 \pm 199.2$  mg cholesterol intake) than non-adherent pesco-veg/semi-veg ( $n = 15$ ,  $-2.3 \pm 200.3$  mg;  $P = 0.02$ ) and omni participants ( $n = 7$ ,  $17.0 \pm 36.0$  mg;  $P = 0.04$ ). In addition, non-adherent vegan/veg participants lost significantly more weight ( $-6.0\% \pm 6.7\%$ ) than non-adherent omni participants ( $-0.4\% \pm 0.6\%$ ;  $P = 0.04$ ), and this comparison approached significance for the non-adherent pesco-veg/semi-veg groups ( $-1.9\% \pm 3.1\%$ ;  $P = 0.06$ ).<sup>[22]</sup> Overall, despite varying methods for assessing diet compliance, it appears that rates of diet adherence are similar across studies regardless of dietary approach. In addition, even if there is incomplete compliance, there are potentially beneficial effects on diet and weight loss when participants receive instruction to adopt PBDs.

#### 4.3 Diet acceptability

Dietary acceptability has been defined as a “user’s judgment of the sum of the advantages and disadvantages of therapeutic diets, which influence the likelihood of adherence.”<sup>[23]</sup> Assessing dietary acceptability in PBDs interventions has included examining frequency of attrition and using acceptability or quality of life questionnaires.<sup>[23]</sup> Several previous PBDs intervention trials have found that participants assigned to a PBDs report high acceptability of the diet, similar to that of comparison diets.<sup>[24-26]</sup> For example, in the New DIETs weight loss intervention discussed above, there were no differences among diet groups in changes in any measures of acceptability including: cognitive restraint of eating, disinhibition, or hunger (assessed by the Three-Factor Eating Questionnaire); the psychological influence of the food environment (assessed by the Power of Food Scale); or dietary acceptability (assessed by the Food Acceptability Questionnaire).<sup>[22]</sup> The New DIETs study also found that dietary preference at baseline (e.g., which diet participants said they did or did not want) had no impact on adherence at six months.<sup>[22]</sup> Going forward, there is a need to standardize dietary acceptability assessment across weight loss interventions using PBDs. This will build an interpretable body of literature around the acceptability of PBDs for the clinical management of obesity.

### 5 Limitations of current PBDs weight loss intervention research

#### 5.1 Use of health behavior theory to promote dietary behavioral change

Public health interventions that use social and behavioral health theories to inform trial design and delivery are considered more effective than those that lack a clear theoretical base, since health theories can be generalized to other programs to provide insight and strategies for designing an effective intervention.<sup>[27]</sup> While there is strong evidence for using health theories in traditional nutrition counseling research to promote weight loss,<sup>[28]</sup> most PBDs studies to date have lacked a clear theoretical basis. Additionally, many of the PBDs clinical weight loss trials have had different behavioral goals, such as focusing on weight loss or managing type 2 diabetes. As a result, the type of participant recruited for each study varied (e.g., overweight participants only, or patients with type 2 diabetes), which may make it difficult to compare one intervention to another.<sup>[9]</sup>

#### 5.2 Need for public health approaches to scale-up interventions

The majority of PBDs weight loss interventions have re-

lied on a group-based delivery model with group meetings held on a weekly, bi-weekly, or monthly basis.<sup>[9,10]</sup> Group-based weight loss programs have been commonly used in other traditional behavioral weight loss interventions and group delivery has been shown to be generally more effective than individually-delivered interventions.<sup>[29]</sup> Group delivery still limits intervention reach and can be time-consuming and costly; therefore, in order to scale up PBDs interventions, delivery methods that go beyond the face-to-face setting are needed. While a few studies have used technology to deliver<sup>[17]</sup> or assist with delivery<sup>[30]</sup> of a PBDs weight loss intervention, more research is needed to examine the effectiveness of implementing PBDs for weight loss via remotely-delivered methods, such as use of the Web, smartphones, or texting.

### 5.3 Reproducing study delivery methods in future studies

There is a general underreporting of the delivery methods and intervention materials used in PBDs clinical weight loss trials, which makes replicating specific strategies challenging for researchers. Regardless of the diet type studied, intervention studies often inadequately report their mode of delivery, processes, dose or intensity, duration, and monitoring systems.<sup>[31,32]</sup> Journal page limits often restrict the author's ability to report all of the strategies and techniques used in their interventions. Limited description of delivery methods also makes it difficult to ascertain what the most effective components were for achieving the desired health outcome. In order to move the field of PBDs weight loss intervention research forward, the use of standard reporting templates, such as the Intervention Description and Replication checklist, should be used in the dissemination of intervention details to make intervention replicability more achievable.<sup>[31]</sup>

## 6 Considerations for an older population

### 6.1 Nutrients to emphasize among older adults following PBDs for weight loss

PBDs can provide adequate nutrition at all stages of the lifecycle including older adults.<sup>[19]</sup> Studies among older adults have found that nutrient density of PBDs may be higher than omni diets,<sup>[33]</sup> however, obtaining adequate intakes of certain nutrients are of concern, regardless of dietary pattern, can be a challenge due to a decrease in caloric intake in older age.<sup>[19]</sup> Nutrients of concern for senior adults include zinc, calcium, iron, and vitamin B12.<sup>[19,33]</sup> Older adults, including those consuming omni diets, may have difficulty absorbing vitamin B12,<sup>[19,34]</sup> so supplementation is

recommended.<sup>[35]</sup> Plant-based dietary zinc sources include soy products, whole grains, nuts, and legumes.<sup>[19]</sup> Beans are also good sources of iron and are soft foods that may be helpful if dentition is less than optimal.<sup>[19]</sup> In addition, plant-based sources of calcium include calcium-fortified juices and plant milks, low oxalate greens, calcium-set tofu, and some beans and seeds.<sup>[19]</sup>

### 6.2 Obesity paradox

Weight loss is associated with lower morbidity,<sup>[36]</sup> but higher mortality in older adults;<sup>[37-39]</sup> a term coined the "obesity paradox." Most previous research has examined the use of calorie-restricted approaches for weight loss in older adults,<sup>[39]</sup> with very little research examining how PBDs may impact this obesity paradox in geriatric populations. More research is needed in older populations in order to examine the role PBDs and weight loss may have on both mortality and morbidity.

## 7 Limitations and future directions

While there is a wealth of both observational and intervention research around the use of PBDs for weight loss, there are still several areas that require future research. There is a need to study use of PBDs for weight loss with more diverse populations, including racial/ethnic minority groups, males, young adults, children, and older adults.<sup>[9,10]</sup> To date, there have been no PBDs weight loss interventions solely among older adults (e.g., ages 65 and older).<sup>[9,10]</sup> In general, most of the weight loss interventions conducted with senior adults using standard diet approaches have been of low-to-moderate quality.<sup>[40]</sup> Moreover, PBDs weight loss trials that last beyond 18 months are needed in order to examine long-term health effects and diet sustainability.<sup>[10]</sup> Another limitation of PBDs weight loss trials conducted to date is that very few reported the physical activity levels of participants. For example, from the Barnard, *et al.*,<sup>[9]</sup> systematic review, only three studies addressed changes in physical activity with two of the studies seeing an increase in physical activity during their interventions<sup>[41,42]</sup> and one reporting physical activity remained unchanged throughout the intervention.<sup>[43]</sup> Lastly, there is a wide variation in what can be defined as a PBD. PBDs are generally defined by what they do not include (e.g., meat, poultry, fish, etc.)<sup>[22,24]</sup> versus what they do include (fruit, vegetables, whole grains, and legumes). A research team recently developed a Plant-based Diet Index (PDI), which gives positive scores to plant foods and negative scores to animal foods in the diet.<sup>[44]</sup> In addition, both healthy and unhealthy PDIs were created that differentiate whole plant foods versus processed

ones.<sup>[44]</sup> The PDI presents a method that can quantify quality of PBDs in future weight loss research.

## 8 Conclusions

In summary, individuals consuming PBDs tend to have lower BMI than those consuming non-PBDs. The adoption of PBDs also appears effective for weight loss. Additional research that examines the use of PBDs for obesity management among more diverse groups and for longer periods of time is needed in order to address weight loss maintenance. Based on the available evidence, however, PBDs should be considered a viable option for patients who are interested in losing weight and improving dietary quality consistent with chronic disease prevention and treatment.

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