

# Erectile Dysfunction - Prevention and Treatment with a Plant-Based Diet



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## Abstract

The main cause of erectile dysfunction (ED) is organic in nature, with vascular etiologies being the most common risk factors. A plant-based diet has a role to play because it can prevent and treat some of the causes of erectile dysfunction, by improving vascular function.

A high level of total cholesterol or low level of high-density-lipoprotein cholesterol (HDL-C) may result in arteriosclerosis and induce erectile dysfunction by arterial insufficiency. Vegetarian and vegan diets can be very efficacious in reducing serum cholesterol. In cross-sectional studies men who report higher fruit and vegetable intake are less likely to have erectile dysfunction.

Diabetes is a common etiologic factor of sexual dysfunction, because it can affect both the blood vessels and the nerves that supply the penis. Obesity is also correlated to the development of several types of dysfunction, including a decrease in sex drive and an increase in episodes of ED.

The plant-based diet has great potential to prevent and treat erectile dysfunction. It includes fruits, vegetables, legumes and should include nuts. The plant-based diet is rich in flavonoids and aids in nitric acid promotion. It reduces the risk of and treats type 2 diabetes, hypercholesterolemia, hypertension, atherosclerosis and coronary artery disease.

**Keywords:** Arteriosclerosis; Corpora Cavernosa; Diabetes; Dyslipidemia; Flavonoids; Hypercholesterolemia; Lifestyle; Penile Smooth Muscle; Penis; Sexual Dysfunction

**Abbreviations:** CVD - Cardiovascular Disease, DM - Diabetes Mellitus, DN - Diabetic Neuropathy, ED - Erectile Dysfunction, IIEF - International Index of Erectile Function, NADPH - Nicotinamide Adenine Dinucleotide Phosphate, NO - Nitric Oxide, PBD - Plant-Based Diet, PCDU - Penile Color Doppler Ultrasound, PCSK9 - Proprotein Convertase Subtilisin/Kexin Type 9 Gene

## Introduction

Improvement of erectile function in men should be added to the growing list of clinical benefits brought about by healthy lifestyles in patients. The main cause of erectile dysfunction (ED) is organic in nature, with vascular etiologies being the most common risk factors. Although there have been sufficient data on the relationship between ED and several well-recognized risk factors, including aging, coronary artery disease, atherosclerosis, diabetes mellitus, dyslipidemia, high blood pressure, and pelvic surgeries, little attention has been paid by physicians to the role of lifestyle factors in ED. A plant-based diet (PBD) has a role to play because it can prevent and treat some of the causes of erectile dysfunction.

## Physiology

Erectile dysfunction is a multidimensional but common male sexual dysfunction that involves an alteration in any of the components of the erectile response, including organic, relational and psychological [1]. Two major aspects of the male erection, the

reflex erection and psychogenic erection, can be involved in the dysfunction and are subject to therapeutic intervention. The reflex erection is achieved by directly touching the penile shaft and is under the control of the peripheral nerves and the lower parts of the spinal cord. The psychogenic erection is achieved by erotic or emotional stimuli, and uses the limbic system of the brain [1].

The human penis is composed of paired corpora cavernosa and the single corpus spongiosum. The corpus cavernosum consists of a meshwork of sinusoidal spaces lined by endothelial cells [2]. The penis remains in its flaccid state when the smooth muscle is contracted. The smooth muscle contraction is regulated by a combination of adrenergic (noradrenaline) control, intrinsic myogenic control and endothelium-derived contracting factors (prostaglandin and endothelins) [2-4].

In order for an erection to occur, relaxation of penile smooth muscle is required to allow blood to flow into the penile structures. The resulting increase in intracavernosal pressure

(ICP) leads to compression of the subtunical venules against the tunica albuginea [2]. This process reduces venous drainage from the corpora cavernosa and increases pressure within the corpora, resulting in an erection. In full rigidity, the ICP reaches values considerably higher than systemic (systolic) blood pressure, with the contribution of the skeletal muscles of the pelvic floor [2].

Upon sexual stimulation, erection occurs after nitric oxide (NO) is released from non-adrenergic noncholinergic (NANC) nerve fibers and acetylcholine is released from parasympathetic cholinergic nerve fibers; the result of the ensuing signaling pathways is increased cyclic GMP (cGMP) concentrations, decreased intracellular Ca<sup>2+</sup> levels and smooth muscle cell relaxation [4,5]. As the smooth muscle relaxes, blood is able to fill the lacunar spaces in the corpora cavernosa, leading to compression of the subtunical venules, thereby blocking the venous outflow (veno-occlusion). The process is reversed as cGMP is hydrolyzed by phosphodiesterase type 5 (PDE5) [4,5]. Erectile dysfunction can occur when any of these processes is interrupted.

Nitric oxide has antiatherogenic (ie, vasodilatory, antioxidant, and anti-inflammatory) effects on vessel walls [6]. Plant-based foods that are high in bioactive polyphenolic compounds have been linked to increased nitric oxide bioavailability and, hence, may provide a mechanism for improved erectile function in Mediterranean and plant-based diets [7].

Reactive oxygen species reduce the bioavailability of nitric oxide and promote endothelial cell dysfunction, [8] believed to be the root cause of vasculogenic erectile dysfunction [9]. Plant-based foods are protective against reactive oxygen species, given their high levels of phytochemical antioxidants.

Medical conditions, such as hypertension, diabetes mellitus, and cardiovascular disease (CVD), and psychological conditions, such as depression and anxiety, also contribute to sexual dysfunction in middle-aged or elderly men. CVD and hypertension cause a narrowing and hardening of the arteries, leading to reduced blood flow to the corporal bodies, which is essential for achieving an erection.

### Epidemiological and Intervention studies

In a cohort study evaluating the association between a healthy dietary pattern, measured by two dietary index scores, and incident erectile dysfunction among men in various age groups, men with the greatest adherence to a Mediterranean or AHEI-2010 (Alternative Healthy Eating Index) dietary pattern were least likely to develop erectile dysfunction. Inverse associations were strongest among men younger than 60 years using AHEI-2010 score; however, men in the highest categories of either dietary index score had the lowest risk of erectile dysfunction in all age groups. These findings suggest that adherence to healthy dietary patterns is associated with lower risk of erectile dysfunction [10].

When dietary index components were examined separately, higher intakes for the most healthy components, including vegetables, fruit, legumes, and fish, were associated with lower risk of incident erectile dysfunction. Lower intakes of the most unhealthy components, including red or processed meat and trans fatty acids, were also associated with lower risk of incident erectile dysfunction [10]. In cross-sectional studies, men who report higher fruit and vegetable intake are less likely to have erectile dysfunction [11-13].

Erectile dysfunction is commonplace after prostate cancer treatment [14]. In a study examining patient-reported outcomes of over 30,000 prostate cancer survivors at 18–42 months after diagnosis, 81% of patients described their overall sexual function as poor or very poor [15,16]. Vegans have a lower risk of prostate cancer, and a plant-based diet can treat early-stage prostate cancer with a Gleason score of less than 7 [17]. Thus their risk of ED is lower because they can avoid prostate cancer in the first place.

### Hypercholesterolemia

A high level of total cholesterol or low level of high-density-lipoprotein cholesterol (HDL-C) may result in arteriosclerosis and induce erectile dysfunction by arterial insufficiency [18]. In older men, reduced blood flow into the penis due to atherosclerotic lesions of the internal iliac, pudendal and cavernosal arteries is the most common cause of erectile dysfunction [19,20].

In one study, men who had organic erectile dysfunction, as verified by abnormal nocturnal penile tumescence and rigidity testing, and who had hypercholesterolemia as their only risk factor, were given atorvastatin for four months with a goal decrease of total cholesterol to less than 200 mg/dl and low-density lipoprotein cholesterol to less than 120 mg/dl. The men's Sexual Health Inventory questionnaire scores improved from 14.2 to 20.7 and measurements showed an increased average penile rigidity at the base [21].

Another study evaluated the effect of correction of serum cholesterol levels on erectile function and sildenafil treatment in patients with erectile dysfunction who have only hypercholesterolemia as a risk factor for erectile dysfunction [22]. Twenty five patients with a single risk factor (hypercholesterolemia, serum cholesterol > 200 mg/dl) for erectile dysfunction were included in the study. The patients were recommended to take sildenafil (minimum two 100 mg tablets/week) one hour before sexual intercourse for 4 weeks. After a one month washout period, the patients then received a single dose of atorvastatin 10 mg/day for one month. Similarly, after a one month washout period, atorvastatin 10 mg/day and sildenafil (minimum two 100 mg tablets/week) were administered for one month as combination therapy. Erectile function was evaluated before and after all treatment regimens using the International Index of Erectile Function (IIEF). Following each treatment modality, mean

IIEF scores were significantly higher than baseline IIEF scores. The IIEF score after sildenafil treatment was significantly higher than in the atorvastatin treatment group and the IIEF score after combined treatment was significantly higher than in the sildenafil and atorvastatin treatment groups [22]. This indicates that even with treatment sildenafil patients will gain better results by treating their hypercholesterolemia. A plant-based diet is effective in treating hypercholesterolemia [23]. Therefore, a plant-based diet can be expected to improve treatment results in patients who take sildenafil.

A study of men with familial hypercholesterolemia showed that treatment with PCSK9 inhibitors showed improvement on Male Sexual Health Questionnaire and on pulse wave velocity. However there was no improvement on the International Index of Erectile Function (IIEF-5) [24]. For these patients, treating their hypercholesterolemia with a plant-based diet may only be partially effective.

Several small- to moderate-sized randomized clinical trials report that multimodal lifestyle and weight loss interventions improve erectile dysfunction among men with significant cardiovascular risk factors [25].

Vegetarian and vegan diets can be very efficacious in reducing serum cholesterol. Patients in a 4-week plant-based diet program had significant reductions in total cholesterol (34mg/dl), LDL-C (25 mg/dl), triglycerides (20mg/dl), hs-CRP (2.5 mg/dl), systolic BP (16 mmHg), and diastolic BP (9 mmHg) [26]. One study showed that a low-fat vegetarian diet was as effective at lowering serum cholesterol as the Standard Heart Association diet plus Lovostatin [27]. This study is notable because it contains nuts in the treatment regimen. There is good evidence that the inclusion of tree nuts, despite their fat content, reduces cardiac risk [28,29].

Another study examining children and their adult parents found that a plant-based, or vegan, diet reduced total cholesterol, LDL cholesterol and C-reactive protein more than the American Heart Association diet. This study is especially important given the recent increase in the incidence of hypercholesterolemia in children and the fact that atherosclerosis seems to start early in life [30].

## Diabetes

Diabetes is a common etiologic factor of sexual dysfunction, because it can affect both the blood vessels and the nerves that supply the penis [31]. Men with diabetes are four times more likely to experience ED, and on average, experience ED 15 years earlier than men without diabetes [32]. Obesity is also correlated to the development of several types of dysfunction, including a decrease in sex drive and an increase in episodes of ED [33].

Erectile dysfunction (ED) is highly prevalent, affecting 35-50% of men with diabetes mellitus (DM) [34]. DM may cause ED through a number of pathophysiological pathways. These include neuropathy, endothelial dysfunction, cavernosal smooth muscle

structural/functional changes, and hormonal changes [35].

Several epidemiologic studies have reported an increased risk of ED in diabetic men [36]. Furthermore, a positive relationship was demonstrated between ED, poor metabolic control and age [37]. These results indicate that diabetes is a significant risk factor for the development of ED.

In diabetes, the severity of ED has been demonstrated to be related to both the severity, [38] and duration of diabetes [39]. However, it is likely that the etiology of ED in diabetes is multifactorial. It is now well established that there is a higher incidence of peripheral neuropathy, autonomic neuropathy, microangiopathy and arterial insufficiency in diabetic patients with ED than in potent diabetic patients.

The pathophysiology of ED in diabetes is not fully understood [40]. Diabetes causes several changes in the neuromuscular system, all of which can contribute to ED. In men with diabetes, there is good evidence that ED is due to failure of nitric oxide (NO)-induced smooth muscle relaxation due to both autonomic neuropathy and endothelium dysfunction [41].

Diabetic neuropathy (DN) is one of the most common diabetic complications, affecting 10%–90% of people with diabetes, depending on the diagnostic criteria and the age and duration of DM [42]. Associated neuropathy or vasculopathy (microangiopathy and generalized vascular disease) is considered to be the most important factor in the pathophysiology of DM-induced ED [40]. Because DN affects all levels of the neural system, disturbances could happen at all levels in the complex process of erection from the central initiation to the penis [42].

Hyperglycemia, which is a main determinant of vascular and microvascular diabetic complications, may participate in the pathogenetic mechanisms of sexual dysfunction in diabetes. Moreover, diabetic patients may present several clinical conditions, including hypertension, overweight and obesity, metabolic syndrome, cigarette smoking, and atherogenic dyslipidemia, which cause endothelial dysfunction [42] and are themselves risk factors for sexual dysfunction [43].

The Mediterranean diet may improve erectile function in men with metabolic syndrome [44]. In one study, the Mediterranean diet reduced the deterioration of sexual function in men newly diagnosed with Type 2 diabetes (T2D) [45]. Yet a completely plant-based diet is more effective in treating T2D than the Mediterranean diet, and is even more efficacious than Metformin [46]. It is therefore likely to be more effective at treating ED in diabetic patients.

## Flavonoids

Higher habitual intake of specific flavonoid rich foods is associated with reduced ED incidence. Flavonoids are present in many plant-based foods/beverages, including fruit, vegetables, tea, herbs, and wine, and exert anti-inflammatory effects,

inhibit LDL oxidation and endothelial NADPH oxidase, modulate endothelial nitric oxide (NO) synthase activity, and augment NO status [47-52]. Increasing evidence supports an improvement in endothelial function and blood pressure after increasing dietary flavonoid intake [47-49, 53-55], suggesting that flavonoids might be more likely than other dietary factors to improve erectile function.

A study of men 18 to 40 years of age showed that the consumption of 50 mg/day flavonoids lowered the risk for erectile dysfunction by 32% [56]. In another study, the reduction of risk of erectile dysfunction for those consuming the most flavonoid rich foods was 9% for flavones, 11% for flavanones and 9% for anthocyanins. Among the subset of men consuming a generally healthful diet, those consuming the most flavones had a 13% risk reduction, and the most anthocyanins had a 12% risk reduction [57].

### Nuts

Erectile function can improve after consuming a Mediterranean dietary pattern rich in plant-based foods, olive oil, nuts, and fish [58]. It is particularly interesting to examine studies on the effect of nuts, since some plant-based dietary patterns encourage nuts, while others avoid them. One study investigated the effects of pistachio nuts on International Index of Erectile Function (IIEF) scores, penile color Doppler ultrasound (PCDU). To evaluate the influence of nuts on erectile function, participants answered to the 15 questions contained in the validated IIEF [59] at baseline and the end of the intervention [60].

Patients with erectile dysfunction were put on a 100g pistachio nuts diet for 3 weeks. IIEF and PCDU were evaluated before and after the pistachio diet [61]. Mean IIEF-15 score was 36 before the diet and 54.2 after the diet, a significant improvement. Similarly, a significant increase in all five domains of IIEF was observed after the diet. Mean peak systolic velocity values before and after the pistachio diet were 35.5 and 43.3 cm/s, respectively (P=0.018) [61].

In a separate 14-week randomized, controlled, parallel feeding trial, participants were allocated to either the usual Western-style diet enriched with 60g/day of a mixture of nuts, or the usual Western-style diet avoiding nuts for the control group. The International Index of Erectile Function (IIEF) questionnaire was used [59]. Compared to the control group, a significant increase in the orgasmic function and sexual desire was observed in the nut-supplemented group during the intervention [60].

### Clinical considerations

Lifestyle changes, diabetes control, and treatment of hypogonadism are important as the first step in ED management since there is no curative treatment for ED [35]. Modifiable lifestyle risk factors for ED include smoking, lack of physical activity, obesity, diet, excessive alcohol consumption, recreational drug use

[62]. Given the large dietary etiologic factor to atherosclerosis, diabetes, diabetic neuropathy and obesity, a plant-based diet has great potential to reduce the risk of and to treat ED.

The American Urologic Association erectile dysfunction guidelines identify cigarette smoking as an independent risk factor for erectile dysfunction [63]. Cigarette smoking contributes to erectile dysfunction by reducing nitric oxide levels and by promoting both reactive oxygen species production and inflammation. Cigarette smoking also directly damages arteries by causing calcification of medial elastic fibers, leading to arterial stiffening and a reduced response to vasodilatory signals [64-66].

Smoking has been shown to have a direct relationship with erectile dysfunction, and a dose response relationship has been suggested because men have increased erectile difficulties with greater numbers of packets of cigarettes smoked or more years of smoking [67-69]. One study suggested that cessation of cigarette smoking can improve erectile function [70].

A meta-analysis regarding exercise and ED showed that moderate and high physical activities were associated with a 37% and 48% lower risk of ED [71]. Several prospective investigations indicate that the physical activity has a beneficial effect on prevention and/or improvements of ED [72-74].

A series of randomized controlled trials has shown positive effects of weight loss on measures of erectile dysfunction [75]. Both clinical trials and observational research indicate an advantage to adoption of plant-based diets for preventing overweight and obesity and promoting weight loss [76,77]. Vegetarians and vegans have significantly lower BMI's on average. A study of American vegetarians and vegans found that that vegetarians had a mean BMI of 25.7 and vegans a mean BMI of 23.6 [78]. A European study found the average BMI of vegetarians and vegans to be 23.3 and 22.4 respectively for men and 22.8 and 21.8 for women [79]. A study of German vegans found an average BMI of 22.3 [80]. A study of vegetarian children found that they too had lower BMI's than their meat-eating counterparts with an average BMI of 17.3 in ages 6 to 11 and average of 20.0 ages 12-18 [81]. One study found the risk of being overweight or obese is 65% less for vegans and 46% less for vegetarians [82].

Erectile dysfunction is a strong predictor for coronary artery disease, and cardiovascular assessment of a non-cardiac patient presenting with erectile dysfunction is recommended [62]. The risk of developing vasculogenic erectile dysfunction is increased in men with hypertension (odds ratio (OR) of 3.04 for those on anti-hypertensive medication, and 1.35 for those not on medication) [18, 67, 73, 83].

Vegetarians have been found to have a 34-44% lower risk of developing hypertension, and a 40% reduced risk of ischemic heart disease. Vegans have a 78% lower risk of type 2 diabetes and a 75% reduced risk of hypertension compared to meat eaters



with an otherwise healthy lifestyle [84]. Thus a plant-based diet is both a valuable prophylaxis and treatment for ED and for several other pathologies.

### Testosterone levels

In comparison with factors such as age and BMI, specific nutrients do not appear to be strong determinants of sex hormone levels [85]. One study found that a plant-based diet is not associated with abnormal testosterone levels [86]. Another study showed that there were no differences between vegans and meat eaters in free testosterone, androstenediol glucuronide or luteinizing hormone [87]. However, observational studies between men from different dietary groups have shown that a vegan diet is associated with small but significant increases in sex-hormone-binding globulin and testosterone concentrations in comparison with meat-eaters [85]. Concern about testosterone levels in vegans is therefore not warranted.

Concern has been expressed about the potential for soy products to reduce testosterone in men. However, a meta study found that neither soy foods nor isoflavone supplements alter measures of bioavailable testosterone concentrations in men [88]. A recent and expanded meta-analysis showed that regardless of dose and study duration, neither soy protein nor isoflavone exposure affects total testosterone (TT), free testosterone (FT), estradiol (E2) or estrone (E1) in men, [89] so there is no need for men to be concerned about consuming soy products.

### Quality of Life

Erectile dysfunction can have a substantial negative effect on a man's quality of life. Many men with erectile dysfunction experience depressive symptoms and anxiety related to sexual performance and avoid engaging in sexual relations. Many men also avoid seeking treatment for their sexual dysfunction [90-93]. The association between the condition and depression is considered to be bidirectional, with the two conditions reinforcing each other in a downward spiral [90]. Importantly, men with depression and erectile dysfunction have lower libidos than men with erectile dysfunction alone, and are less likely to discuss their erectile dysfunction with their partners [92,94].

Oral PDE-5 inhibitors are first-line treatments for ED [95]. Sexual stimulation is needed to produce an erection; the PDE-5 inhibitor helps to maintain the erection by enhancing the vasodilatory effects of endogenous nitric oxide [96].

Various medications have also been shown to be associated with the development of erectile dysfunction [83]. Medications that are used to treat hypertension (thiazide diuretics and  $\beta$ -blockers) are most commonly associated with erectile dysfunction, but others, including psychotherapeutics, anti-androgens, anti-ulcer drugs, opiates and digoxin, have also been linked with the condition [83].

Hyperprolactinemia from a pituitary adenoma is a rare cause

of erectile dysfunction. Men with erectile dysfunction who are found to have a low testosterone level should have a measurement of their prolactin level [97]. Total testosterone and sex hormone-binding globulin for the evaluation of calculated free testosterone are sufficient parameters to rule out hypogonadism [98,99].

### Discussion

The plant-based diet has great potential to prevent and treat erectile dysfunction. It includes fruits, vegetables, legumes, whole grains, and should include nuts. The plant-based diet is rich in flavonoids and aids in nitric acid promotion. It reduces the risk of and treats type 2 diabetes, hypercholesterolemia, hypertension, atherosclerosis and coronary artery disease.

Vegans have lower BMIs and the plant-based diet is an effective treatment for obesity. In addition, vegans have a lower risk of prostate cancer. A plant-based diet can slow or halt the progression of prostate cancer with a Gleason score less than 7. Plant-based diets can also prevent and treat comorbidities such as cardiovascular disease, type 2 diabetes and hypertension and prostate cancer.

Treating the patient with ED with a plant-based diet represents a valuable additional treatment to the currently used methods. It is important to note that testosterone levels are normal in vegan men.

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