The Health Benefits of Fruits and Vegetables

A Scientific Overview for Health Professionals

A review of the literature from 1999 to 2001 by Dianne Hyson, Ph.D., M.S., R.D.

Produce for Better Health® Foundation

Table of Contents

Forward

The science behind the health benefits of eating fruits and vegetables is exploding greater than ever before. Researchers are learning more about phytonutrients, traditional nutrients, and the role that diet plays in disease prevention. This booklet reviews the research behind eating more fruits and vegetables and many types of cancer, cardiovascular disease, hypertension, chronic obstructive pulmonary disease, diabetes, obesity, longevity, bone health, aging, neurodegenerative diseases, and many other diseases.

We encourage a "foods first" approach to eating. Whenever possible, we should aim to get our nutrients from foods. Foods are very complex by nature and we are learning more about the interactions among foods and their constituents, such as fiber, nutrients, and phytonutrients that strengthen their health-promoting abilities. We refer to this as "food synergy." We also know there are many components in foods yet to be identified that we will need to learn about. Consumption of fruits, vegetables, whole grains, nuts, legumes, and other plant-based foods should be the primary dietary approach to disease prevention, rather than individual nutrient or food components.

To change dietary behaviors and get people to eat 5 to 9 servings of fruits and vegetables daily, depending on their caloric needs, we need to work together as health professionals to interpret the science and make strong policy and programmatic decisions based on that science. Not all foods are created equally. Some are more nutritious that others. A colorful variety of all fruits and vegetables, healthfully prepared, makes a significant contribution to a diet that promotes good health.

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Introduction

There is a great deal of interest in the association between fruit and vegetable consumption and human health. Because oxidative stress plays a significant role in most disease processes and aging, the potential health benefits of fruits and vegetables have been largely attributed to their potential antioxidant capacity. While this remains the focus of many studies, recent data indicate that the protective effect of fruits and vegetables may extend beyond their antioxidant capacity.

The majority of data showing a beneficial effect of fruit and vegetable intake on risk of disease, particularly cancer and coronary artery disease, have historically been obtained from case-control studies. Recently, an increasing number of prospective trials have been conducted to determine if fruit and vegetable intake affects the development of these conditions over an extended period of time. While the results of the newer prospective trials have been less conclusive than earlier case-control studies, the current evidence collectively demonstrates that fruit and vegetable intake is associated with improved health, reduced risk of major diseases, and possibly delayed onset of age-related indicators. This review provides an update of literature published between 1999-2001 related to fruit and vegetable intake and several health issues.

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Cancer

In the United States, 1 of every 4 deaths is attributed to cancer, totaling over 500,000 deaths per year (1). In the year 2001, 1,268,000 new cancer cases were anticipated. The National Institutes of Health estimated that overall costs for cancer were $180.2 billion in 2001 (1). The importance of dietary factors in the etiology of most cancers is well recognized and has been summarized in past reports including that of the American Institute for Cancer Research published in 1997 (2). Fruits and vegetables are among the most widely studied dietary risk factors for cancer (3). The current evidence is summarized in the following section according to the most common sites of cancer.

Cancer of the lung and bronchus is the leading cause of cancer death in men and women, with an estimated 157,400 deaths anticipated in 2001 (1). A variety of early reports showed an inverse relationship between fruit and vegetable intake and lung cancer and recent data support this association.

American women (Nurses' Health Study) in the highest quintile of fruit, vegetable, or combined fruit and vegetable intake had a 21-32% lower risk of lung cancer, with vegetable intake being statistically significant (4). Lung cancer risk was notably elevated among women consuming less than 2 servings of fruits and vegetables per day. The greatest protection was associated with intake of cruciferous vegetables (broccoli, cauliflower, brussel sprouts, cabbage), citrus fruits, and foods high in total carotenoids. Consistent with these data, strong inverse associations between intake of cruciferous vegetables and citrus fruits and lung cancer risk were reported in a cohort study in the Netherlands (5). Furthermore, prospective data from the American nurses (above) and men (in the Health Professionals' Follow-Up Study) showed an inverse association between lung cancer risk and intake of total carotenoids and ß-carotene (6), although fruit and vegetable intake was not associated with lung cancer risk in men.

Data from an ethnically diverse population in Hawaii showed a significant inverse association between lung cancer risk and consumption of foods rich in the flavonoid quercetin, including apples and onions (7). White grapefruit, an excellent source of the flavonoid naringen, was also protective. Total quercetin content of the diet tended to be associated with reduced risk although the effect was not significant.

The smoking status of an individual may be an important determinant of potential benefits associated with fruit and vegetable consumption. Recent data from a 25-year study of European men showed that fruit intake was associated with reduced risk of lung cancer, but the beneficial effect was limited to heavy smokers (8).

These results suggest that while not all studies of lung cancer and fruit and vegetable intake have shown statistically significant results, most prospective data suggest trends in the direction of a positive benefit. There is clearly a need for well-controlled intervention studies to further clarify the association between fruit and vegetable intake and lung cancer risk.

Breast cancer accounts for 31% of all cancer diagnoses and 15% of cancer deaths anticipated in females in 2001(1). Although dietary variables have been implicated in the development of breast cancer in case-control studies, a recent report that analyzed the collective data from 8 prospective trials found no association between intake of fruits and vegetables and reduced risk of breast cancer (9). Breast cancer risk was 3 to 9% lower in women in the highest decile of fruit or vegetable intake compared with the lowest decile but this reduction was not statistically significant.

Some studies including an analysis of specific subcategories of fruit and vegetable intake have shown that consumption of cruciferous vegetables might be protective against breast cancer. A recent case-control study found that cruciferous consumption (1-2 servings per day) reduced breast cancer risk by 40-50% in post-menopausal women (3, 10). Studies of biomarkers for breast cancer risk support a potential protective effect for cruciferous vegetables. In postmenopausal women, increasing daily intake of cruciferous vegetables from 9 grams to 193 grams (2 servings/day) resulted in a favorable shift in the ratio of urinary 2-hydroxysterone to 16- α hydroxysterone (11). These estrogen metabolites have been implicated as endocrine biomarkers for breast cancer. The average consumption of cruciferous vegetables in the United States is estimated to be 5-11 grams per day, well below the average intake in the above study (11). Thus, the available data seem to indicate a potential protective effect of some vegetables on risk of breast cancer. The association between breast cancer and total fruit and vegetable intake is less clear.

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Prostate cancer is the leading cancer diagnosis in men and accounts for 11% of anticipated deaths in males in 2001(1). There are very few studies linking fruit and vegetable intake with prostate cancer risk although a recent case-control study did show an inverse association between prostate cancer and intake of vegetables (35% reduced risk) and particularly cruciferous vegetables (41% reduced risk) (12). It has been suggested that lycopene, found mostly in tomatoes, may also be protective (3) although this finding has not been consistent. Clearly, further study is needed to determine the effect of cruciferous vegetables and tomatoes on risk of prostate cancer.

Cancers of the colon and rectum are equally distributed among men and women, accounting for approximately 10% of new cancer cases and 10% of expected cancer deaths in 2001(1). The majority of case-control studies published in the past showed an inverse association between fruit and vegetable consumption and colorectal cancer risk [reviewed in Steinmetz and Potter, 1996 (13)]. However, results from several recent prospective investigations have not consistently shown this effect.

The protective effects of fruits and vegetables on colorectal cancer risk might be less evident in study subjects who have a higher intake of these foods and/or regularly use a multiple-vitamin supplement (14). Terry et al. studied Swedish women with a wide range of fruit and vegetable intake over 9.6 years (14). They found an inverse association between colorectal cancer and total fruit and vegetable consumption, particularly among women who consumed very low amounts of fruits and vegetables. The authors concluded that increased fruit and vegetable consumption might be most beneficial for individuals who consume less than 2 servings of fruits and vegetables per day. In two large American cohorts of men and women, the majority of subjects consumed more than 2 servings of fruits and vegetables per day and over 30% used multiple vitamins. It is possible that these factors may have accounted, in part, for the lack of an association between fruit and vegetable intake and colon/rectal cancer incidence over a 10-16 year period (15).

Specific subsites of colorectal cancer may be affected by vegetable intake. In the Netherlands Cohort Study on Diet and Cancer vegetables, particularly cruciferous and cooked leafy vegetables, were more protective for distal than proximal colon cancers (16).

In summary, prospective studies have not provided conclusive evidence that fruit and vegetable consumption reduces risk of colorectal cancer (17). Clinical intervention studies are needed to provide additional data.

Non-Hodgkin's Lymphoma is the fifth leading cause of cancer death in men and sixth in women (1). There is limited evidence on the relationship between fruit and vegetable intake and risk of Non-Hodgkin's lymphoma but available studies suggest an inverse relationship. Data from 88,410 women enrolled in the Nurses' Health study showed that fruit and vegetable intake was associated with reduced risk of this cancer (18). The protective association was stronger for vegetables than for fruits. Consumption of 3 or more vegetable servings per day was associated with 38% lower risk compared to consumption of 1 or fewer vegetable servings per day. Women who consumed 3 or more servings/day of fruits had a 30% lower risk compared to women consuming 1 serving. A higher intake of cruciferous vegetables was specifically associated with a reduced risk. Women who consumed 5 or more servings of cruciferous vegetables had a 33% lower risk than women consuming 2 or fewer servings per week.

These data differ somewhat from an earlier case-control study that reported reduced risk of Non-Hodgkin's lymphoma associated with citrus fruit and dark green vegetable consumption in men, but not for women (3). Further research is needed to conclusively define the effects of fruit and vegetable intake on risk of Non-Hodgkin's lymphoma.

It was expected that **ovarian cancer** would be diagnosed in 23,400 women in the U.S., accounting for 4% of newly diagnosed cancers in 2001 (1). Recent case-control studies have reported a protective effect of fruits and vegetables on risk of this cancer. There was a 40% decrease in ovarian cancer incidence among women in the highest quartile of total fruit and vegetable intake (>164 grams/day) compared to women in the lowest quartile (<80 grams/day) (19). There was also reduced risk in women consuming higher amounts of dietary fiber, total vitamin A, total carotenoids, vitamin E, and ß-carotene.

A population based case-control study including pre- and post-menopausal women demonstrated that several micronutrients found in fruits and vegetables were associated with reduced risk of ovarian cancer (20). Total carotene, α-carotene, and ß-carotene intake were associated with significantly decreased risk in post-menopausal women and lycopene intake appeared to be protective in pre-menopausal women. Consistent with these observations, foods known to be rich sources of these nutrients were most clearly associated with decreased risk for ovarian cancer. Women consuming 2 or more servings (1/2 cup each) of tomato sauce per week had a 40% decrease in risk of ovarian cancer compared to women eating tomato sauce less than once a month. Women consuming 5 or more servings of raw carrots per week (4 cut sticks) had a 54% reduction in risk of ovarian cancer compared to women eating carrots less than once a month.

"...Citrus fruit intake was associated with reduced incidence (of esophageal cancer) in the Italian population. Individuals with higher fruit and vegetable consumption (4-6 servings per day) have been shown to have 40-60% lower risk of esophageal cancer compared to those who consume 1-2 fruit and vegetable servings per day."

Although more study is needed, the available data are suggestive of an inverse relationship between fruit and vegetable consumption, particularly carotenoid rich-sources, and risk of ovarian cancer.

Esophageal cancer was expected to account for 3% of all cancer deaths in American males in 2001(1). Until recently, squamous cell esophageal cancer was relatively rare in women, but rates have been on the rise in several countries over the past decade (21). Several newly published case-control studies support earlier data suggesting that fruit and vegetable consumption reduces risk of esophageal cancer. A recent composite analysis of case-control data from South America (22) and several case-control studies using populations in Uruguay, Italy, and Switzerland (21, 23, 24) have shown that intake of vegetables (cooked and raw), fruit, and combined fruits and vegetables is associated with reduced risk of carcinoma of the esophagus. Citrus fruit intake was associated with reduced incidence in the Italian population. Individuals with higher fruit and vegetable consumption (4-6 servings per day) have been shown to have 40-60% lower risk of esophageal cancer compared to those who consume 1-2 fruit and vegetable servings per day (3). In some studies the risk reduction remained significant after adjustment for antioxidant content, suggesting that other bioactive constituents in fruits and vegetables might account for the protective effect.

Thus, the bulk of evidence, although based primarily on case-control studies, suggests that consumption of vegetables and particularly fruits, reduces risk of squamous esophageal cancer. However, because the incidence of esophageal cancer is relatively low in affluent countries, there are no prospective data available regarding the association.

Cancers of the oral cavity were expected to account for 3% of all newly diagnosed cancers in U.S. males in 2001(1). Recent and past case-control studies have shown an inverse relationship between fruit and vegetable intake and cancers of the oral cavity, pharynx, and larynx (3, 13). In countries with a high prevalence of laryngeal cancer, raw vegetable intake was associated with the greatest reduction in risk (25). There was also a significant risk reduction with total fruit intake, and total fruit and vegetable intake, but not cooked vegetables. An analysis of several individual food items showed that tomatoes, lettuce, and oranges were associated with the strongest decrease in the risk of laryngeal cancer (65-68%), although several other fruits and vegetables also provided significant protection.

Bladder cancer was predicted to be the 9th leading cause of cancer death in men in 2001 (1). Two recent prospective trials and a meta-analysis provide general support for an inverse association between fruit and vegetable consumption and bladder cancer (26-28). In Japanese atomic-bomb survivors, consuming green-yellow vegetables several times a week (2-4 times every day) reduced risk of bladder cancer by 38-46% (26). There was a marginally significant protective effect for fruit as well. In an American cohort of male health professionals, intake of cruciferous vegetables was associated with reduced incidence of bladder cancer (28). These recent studies provide support for several earlier case-control studies showing that specific vegetables may be protective against the development of bladder cancer. However, studies of bladder cancer are confounded by the relatively low incidence rate.

Early case-control studies showed mixed results in relation to **endometrial cancer** risk and fruit and vegetable consumption (3). Several recent case-control studies have suggested a protective effect of consuming fruits, vegetables, or a combination of both although the association may be diminished after adjustment for body mass index. (29). Reduced risk of endometrial cancer may be associated with intake of specific items including dark green/deep yellow fruits and vegetables (34% lower risk) and cruciferous vegetables (34% lower risk). Two other case-control studies showed an inverse association between endometrial cancer and vegetable, but not fruit, intake (30, 31).

Stomach cancer has been widely studied for dietary effects (3). The majority of case-control studies support a positive association between fruit and vegetable intake and reduced risk of stomach cancer (3). However, recent prospective trials have provided mixed results. In a 14-year follow-up study of 1.2 million men and women in the United States, there was no association between specific food groups and risk of stomach cancer (32). An overall diet pattern associated with increased intake of plant foods (sum of vegetables, citrus fruit, and whole grains) reduced risk by 21% in men (highest versus lowest tertile), but this association was not evident in women. At least two European prospective studies have found no association between fruit and vegetable intake and stomach cancer while two others have noted an inverse effect (3). The reasons for this discrepancy are not clear and further study is needed to define the true effect of fruit and vegetable intake on risk of developing stomach cancer.

In conclusion, fruit and vegetable consumption is among the many factors that might influence the risk of developing cancer. Due to the complex etiology and the varied forms of different cancers, there are still many unresolved questions regarding the true association between fruit and vegetable intake and cancer risk. However, while the prospective studies are less convincing than the case-control studies, there are ample data to suggest that fruit and vegetable intake is likely to be protective for most cancers. Current investigations are beginning to move toward focusing on biomarkers of cancer risk and examination of plausible mechanisms by which fruit and vegetable intake might be protective. The ongoing work promises to provide important information to characterize the association between fruit and vegetable consumption and cancer.

Cardiovascular Disease

Coronary artery disease and stroke, two principal manifestations of cardiovascular disease (CVD), account for nearly 40% of all deaths in the U.S., killing almost a million people each year (33). It is estimated that 61,800,000 Americans currently have one or more forms of CVD, predominantly hypertension and coronary artery disease (34). The costs of CVD are staggering – an estimated cost of $289.2 billion in 2001 and anticipated $329.2 billion in 2002.

Lifestyle changes, including dietary factors, have great potential to reduce mortality and morbidity associated with CVD. There is a diverse array of substances in fruits and vegetables associated with decreased risk of CVD including antioxidants, folate, fiber, potassium, flavonoids, or other phytochemicals. A number of past reports have summarized data from case-control studies showing a beneficial effect of fruit and vegetable consumption on risk of CVD. Recent prospective studies have added to the growing evidence that fruit and vegetable intake reduces risk factors as well as incidence and mortality associated with CVD.

"...data from women in the Nurses' Health Study and men in the Health Professionals' Follow-Up Study showed that men and women in the highest quintile of fruit and vegetable intake (9 and 10 servings per day for women and men, respectfully) had a 20% lower risk of coronary artery disease compared to those with the lowest intake (2.5-3 servings per day)."

Recent 12-year follow-up data from the Nurses' Health Study (n>69,000) showed that a "prudent" pattern, characterized by high intakes of fruits, vegetables, whole grains, and use of low-fat dairy products is associated with reduced risk of cardiovascular events and risk factors compared to a "Western" pattern of higher intake of fat, red and processed meat, eggs, butter, and refined grains (35). The protective effect for coronary artery disease remained even after adjustment for differences in dietary folate, fiber, vitamin supplements, alcohol, saturated and monounsaturated fat, and smoking. Within the prudent diet, women in the highest quintiles of the prudent-diet pattern scores had lower risk for incidence and fatal outcomes of coronary artery disease, and nonfatal myocardial infarction.

Another recent report of combined data from women in the Nurses' Health Study (n>84,000) and men in the Health Professionals' Follow-Up Study (n>42,000) showed that men and women in the highest quintile of fruit and vegetable intake (9 and 10 servings per day for women or men, recspectfully) had a 20% lower risk of coronary artery disease compared to those with the lowest intake (2.5 - 3 servings per day) (36). The lowest risks were observed for green leafy vegetables and vitamin C-rich fruits and vegetables. It was calculated that there was a 4% lower risk of coronary artery disease for each 1 serving per day increase in fruit and vegetable intake. The median intake of total fruits and vegetables was 5.8 servings/day for women followed for 14 years and 5.1 servings/day for men followed for 8 years. In a separate study group of physicians followed for 12 years, (n=15,220) the incidence of coronary artery disease was approximately 25% lower in men who consumed 2.5 servings of vegetables per day compared to those who consumed less than 1 serving per day (37). The protective association was strongest among men with a body mass index over 25 and among current smokers.

A 5-year prospective study of 39,127 female health professionals enrolled in the Women's Health Study provided evidence of an inverse association between fruit and vegetable consumption and risk of myocardial infarction (38). Women in the highest quintile of fruit and vegetable intake (>10 servings/day) had a 38% lower risk of myocardial infarction compared to women consuming 2.6 or fewer servings per day. There was also an inverse relationship between fruit and vegetable consumption and incidence of CVD, although this was not statistically significant when known cardiovascular risk factors were considered.

In addition to prospective studies, a number of small clinical trials have been conducted to examine the effects of diets containing fruits and vegetables on plasma lipids and other biomarkers associated with risk of cardiovascular disease.

Plasma homocysteine levels are positively correlated with the development of coronary artery disease by several potential mechanisms including endothelial cell toxicity, oxidation of LDL, effects on coagulation, and stimulation of smooth muscle cell proliferation (39). Since dietary folate is a co-substrate in homocysteine metabolism, folic acid supplementation, and high dietary folate intake reduce levels of plasma homocysteine and presumably lower risk of coronary artery disease [reviewed in (39)]. Recently, it has been demonstrated that dietary folate from fruits and vegetables reduces plasma homocysteine levels (40-42). A clinical trial including healthy men and women in the Netherlands demonstrated that 4 weeks of consuming dietary folate provided by citrus fruit and green vegetables resulted in a significant reduction in plasma homocysteine levels (40). In two other clinical trials, dietary intake of a mix of fruits and vegetables with moderate folate content was associated with a significant reduction (11%) in plasma homocysteine levels in healthy subjects (41, 42). This may be one important mechanism by which fruit and vegetable intake is associated with reduced risk of cardiovascular disease.

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Diets high in fruits and vegetables have also been shown to reduce plasma lipid levels. In a recent metabolic diet study using a cross-over design, 10 healthy subjects were provided a diet containing very high fiber from fruits and vegetables (55 grams fiber/1,000 kcal) for a 2 week period (43). The high fiber diet included leafy vegetables and pods, fruits, and nuts. Compared to two control diets (a starch-based and a low-fat diet) the high fiber intake resulted in the largest reduction in plasma levels of total and LDL cholesterol (22% and 33% reductions, respectively) as well as a 24% reduction in the ratio of LDL:HDL cholesterol. The investigators also reported that the high fiber fruit and vegetable diet had positive effects on markers of risk for colon cancer.

The Dietary Approaches to Stop Hypertension (DASH) Trail has examined the effect of increasing fruit and vegetable consumption on plasma lipid levels. (44). In the DASH Trial, 436 participants were randomly assigned to 8 weeks of either a control diet, a diet increased in fruits and vegetables (8.5 or more servings), or a diet with increased fruits and vegetables in the background of a low-fat and cholesterol, low-fat dairy diet (DASH diet). There was a trend toward reduced total cholesterol levels in men and reduced triglyceride levels in non-African Americans in the fruit and vegetable diet compared to controls. The DASH diet resulted in significantly reduced plasma levels of total, LDL and HDL cholesterol in all races and both sexes compared to the control diet. The fruit and vegetable diet and DASH diet are known to effectively reduce blood pressure (45), an important CVD risk factor, as discussed in a subsequent section (see Hypertension).

Oxidative processes are important in the development of CVD and have been the focus of several intervention studies. The beneficial effect of fruits and vegetables on CVD risk is likely due, in part, to their potential antioxidant activity. Fruit and vegetable intake increases antioxidant capacity of plasma in a short time after consumption. A small study of elderly women (n=8) found that total antioxidant capacity of plasma was increased by 7-25% within 4 hours of consuming antioxidant rich foods or vitamins, including strawberries, spinach, wine, or vitamin C (46). Similarly, cranberry juice consumption increased total antioxidant capacity of plasma for 1-4 hours in 9 healthy women aged 23-41 years (47). This effect has been ascribed to the phenolic compounds present in fruits and vegetables and in some cases, the vitamin C content. Consumption of carotenoid-rich fruits and vegetables is associated with increased plasma levels of carotenoids (41, 42, 48, 49) and may raise carotenoids in the lipoprotein fraction of plasma (50). However, increased plasma levels of carotenoids do not always result in improved antioxidant capacity (51, 52).

Oxidative processes are thought to promote the uptake of LDL cholesterol into macrophages in the arterial wall and promote the initiation and development of coronary artery disease (53). The oxidation potential of LDL cholesterol in plasma is commonly used as a biomarker of risk for CVD.

Several, but not all, studies have found that consumption of fruits and vegetables, either as extracts, or part of a total diet, effectively reduce the oxidation rate of LDL and/or delay the onset of LDL oxidation (50, 54, 55).

The effect of fruit and vegetable intake on oxidation-related biomarkers appears to be influenced by lifestyle and/or disease-related factors. For example, individuals who smoke may be less likely to demonstrate improved antioxidant status upon fruit and vegetable supplementation compared to non-smokers (52, 54). In a recent study, subjects who were HIV-seropositive demonstrated increases in plasma antioxidant capacity after 16 weeks of supplementation with fruit juice or fruit-vegetable concentrate in contrast to HIV-seronegative subjects who showed no change in antioxidant status after the supplementation (56).

In conclusion, there is strong evidence supporting current dietary recommendations to emphasize fruits and vegetables in dietary strategies aimed at reducing risk of CVD. Furthermore, there are a variety of bioactive components and nutrients in fruits and vegetables and plausible mechanisms explaining how they might be protective.

Hypertension

Hypertension or high blood pressure affects over 50 million people in the United States (34). The well-publicized Dietary Approaches to Stop Hypertension (DASH) Trial showed that fruit and vegetable intake, (8.5 servings or more per day) particularly in combination with low-fat dairy products, effectively lowers blood pressure in subjects with normal and high blood pressure (45). High blood pressure is typically defined as systolic blood pressure greater than 140 mm Hg or diastolic blood pressure over 90 mm Hg. Recently, a detailed report of the effects of the DASH diet on subgroups of subjects with Stage 1 hypertension (systolic 140-159 mm Hg and/or diastolic blood pressure 90-95 mm Hg) was published (57). The DASH combination diet, including high fruit and vegetable intake, low-fat dairy products, whole grains, poultry, fish, and nuts was effective in controlling hypertension in 70% of the participants with Stage 1 hypertension. A diet high in fruits and vegetables also lowered blood pressure in this group but to a lesser extent. Results were observed within 2 weeks of dietary modification and were sustained throughout the 8-week intervention period.

Subjects with normal diastolic but elevated systolic blood pressure (> 140 mmHg) are designated as having "isolated systolic hypertension" or ISH. ISH is probably the most common form of untreated hypertension and is associated with increased risk of cardiovascular death (58). In a recent report analyzing a DASH Trial subgroup (n=72) with ISH, it was found that the 8-week DASH diet was effective in reducing both systolic and diastolic blood pressure.

These data from the DASH Trial suggest that diets including a high intake of fruits and vegetables are effective at reducing blood pressure in subgroups of the population with various forms of hypertension. The nutrients accounting for the reduction in blood pressure have not been defined but potassium likely accounts for the effects observed with fruit and vegetable intake. A number of studies have also suggested that flavonoids in fruits and vegetables are protective for stroke, for which hypertension is a major risk factor (59). Whether flavonoids directly affect blood pressure is unknown.

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Stroke

Over 4.6 million Americans have experienced a stroke (34). In a recent report, data from 14 years of follow-up for women in the Nurses' Health Study and 8 years for men in the Health Professionals' Follow-Up Study showed that total fruit and vegetable consumption was inversely related to risk of stroke in both sexes (60). In women there was a 26% risk reduction for those in the top quintile of fruit and vegetable consumption (median 10.2 servings/day) compared to the lowest quintile (2.9 servings/day). For men, the risk reduction between the top quintile (median 9.2 servings/day) and lowest quintile (2.6 servings/day) was 39%. The lowest risks were observed for high consumption of cruciferous vegetables, green leafy vegetables, citrus fruits, and vitamin-C rich fruits and vegetables. Each increment (1 serving/day) of total fruits and vegetables reduced risk of stroke by 3% among women and 5% among men. Slightly stronger protective effects were observed in the subjects who did not use multivitamin supplements than in those who regularly used supplements.

This new report provides additional support for previous data from these cohorts and other studies showing an inverse association between fruit and vegetable intake and dietary flavonoid composition and incidence of stroke.

Chronic Obstructive Pulmonary Disease and Lung Function

Asthma and chronic obstructive pulmonary disease (COPD – primarily chronic bronchitis and emphysema) are diseases of the lung airways. In 1996, over 14 million cases each of chronic bronchitis and asthma were reported in the United States (61). Over 2 million people had emphysema. COPD deaths ranked 4th in the country.

The etiology of these diseases may involve oxidative processes. Antioxidants and foods that are rich in antioxidants, including fruit, have been proposed to protect airways against oxidant-mediated damage (62). Smit et al. reviewed the available epidemiological data in 1999 and concluded that there was increasing evidence for a beneficial effect of fruit and vegetable consumption on indicators of asthma and COPD(63). Several recent studies have added to the data suggesting a positive association between fruit consumption and lung health, particularly in middle-aged men (62, 64, 65). A cross-sectional study of men in Finland, Italy, and the Netherlands showed that men consuming higher amounts of fruit (above median intake of 117-150 grams per day) had significantly higher forced expiratory volume (FEV), a measure of pulmonary function (62). Antioxidant intake (vitamin C, vitamin E, and ß-carotene) above the median tended to be positively associated with pulmonary function although not statistically significant. A cross-sectional study of 2512 Welshmen (aged 45-59) used more advanced technology to measure FEV than the above investigation and confirmed that intake of fruits, and to a lesser extent vegetables, was associated with improved lung function (65). Apples appeared to be particularly protective. During five years of follow-up of the men in the Welsh study it was found that eating five or more apples per week tended to delay a decline in lung function.

A protective effect of apples on lung function was also observed in a more recent cross-sectional study of men and women living in three Dutch cities (64). The goal of the study was to determine the relationship between self-reported COPD symptoms, pulmonary function, and dietary intake of several flavonoids. Apples and onions were the main source (after tea) of the flavonoids being studied (catechins, flavonols, and flavones). Catechin intake showed a beneficial association with FEV and all COPD symptoms. Flavonol and flavone intake was associated with reduced prevalence of chronic cough but not FEV. An average intake of 55 grams/day of solid fruits (including apples and pears) was positively associated with FEV and inversely associated with COPD symptoms. Similar, but slightly weaker associations, were reported with intake of citrus and other fruits. Importantly, the main dietary source of flavonoids in this study was tea, but tea intake was not associated with pulmonary function or COPD. This suggests that fruit might contain a mixture of protective compounds beyond the flavonoids examined in this study.

These observational studies demonstrate a positive association between fruit and vegetable (particularly fruit) intake and pulmonary function and support earlier work suggesting a beneficial effect of fruit and vegetable intake. However, it will be important to see if dietary intervention studies confirm the potential benefits.

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Diabetes

Diabetes is the 6th leading cause of death in Americans and is associated with increased CVD, stroke, hypertension, blindness, kidney disease, and amputation (66). Over 7 million Americans had diabetes in 1996. The prevalence of diabetes rose by 6% during 1999 and has become a significant public health problem in the United States (66).

A small number of studies have suggested that fruit and vegetable consumption is associated with reduced risk of developing diabetes and improved control of blood sugar levels. An analysis of 20-year follow-up data from nearly 10,000 men and women who had completed 24-hour baseline dietary recalls in the first National Health and Nutrition Examination Survey (NHANES I, 1971-1975) (67) showed that individuals in the cohort who developed diabetes had lower mean intakes of fruits and vegetables. The percentage of subjects consuming five or more servings of fruits and vegetables was significantly lower among subjects who developed diabetes. In diabetic men and women, only 19% consumed five or more servings of fruits and vegetables compared to 26% of non-diabetic men and 30% of non-diabetic women consuming five or more servings per day. Furthermore, women consuming five or more servings of fruits and vegetables per day experienced a 39% reduction in diabetes risk compared to women who consumed little or no fruits and vegetables. These analyses, based on a single 24-hour dietary recall must be viewed cautiously although the long period of follow-up and multiple adjustments for potential confounding variables improve the validity of the findings. However, these results are in contrast to another prospective study published recently in which fruit and vegetable intake was not directly associated with incidence of type 2 diabetes in older women followed prospectively for 6 years in the Iowa Women's Healthy Study (68).

The association between fruit and vegetable intake and glucose levels was studied in over 6,000 non-diabetic men and women in the United Kingdom in the European Prospective Investigation into Cancer [EPIC-Norfolk, (69)]. Glycosylated hemoglobin (HbA_{1C}) levels, an indicator of long-term blood glucose control, tended to be higher in subjects with the lowest consumption of fruit and green leafy vegetables after adjustment for dietary fiber, dietary and plasma vitamin C, and a number of other potential confounders. It is important to determine if a similar association is present in individuals with diabetes or impaired glucose tolerance.

There are a number of possible mechanisms by which fruit and vegetable consumption might reduce risk of diabetes including positive effects on the control of glucose and peripheral insulin sensitivity mediated by fiber and magnesium, as well as potential benefits from antioxidant vitamins and phytochemicals found in fruits and vegetables. In view of the striking increase in the prevalence of diabetes, further study of potential benefits of fruit and vegetable consumption on risk and control of diabetes is important.

Obesity

Over 60% of American adults are overweight (body mass index ≥ 25) and of these, 26% are obese (body mass index ≥ 30) (70). In young Americans the prevalence of overweight is also increasing, with the latest estimates suggesting that 11% of children and adolescents are overweight. The total cost of overweight and obesity is estimated to be $99.2 billion, representing 5.7% of annual U.S. health-care costs (70).

A long-term imbalance between energy intake and expenditure is important in the development of overweight and obesity (71). There is a great deal of interest in the specific dietary factors associated with the prevention of overeating. Although not fully understood it is thought that energy density, fiber content, palatability, and dietary variety are thought to be important determinants of energy consumption (71-73). Inclusion of fruits and vegetables in the diet has the potential to affect each of these factors.

McCrory et al. reported that obesity is associated with consumption of foods high in energy density (74). Conversely, intake of fruits and vegetables (fried potatoes excluded) were among the foods that were negative predictors of body mass index. Rolls and colleagues have extensively examined the relationship between varying energy density of foods and subsequent energy intake. Adding vegetables with high water content to lunch and dinner entrées lowered the energy density of the entrées but did not affect palatability or feelings of fullness and hunger compared to the same entrée without the added vegetables (i.e. higher energy density) (72). Importantly, consuming the entrées with the added vegetables resulted in a 30% reduction in total energy intake for the day. Other studies in normal and overweight women have confirmed that total daily energy intake is lowered by up to 20% when consuming foods of low energy density without excessive feelings of hunger (75). These studies suggest that consuming foods of low energy density, including vegetables and some fruits, may be a useful strategy for weight loss.

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In general, dietary variety is positively associated with higher energy intake. It has been proposed that the rising prevalence of obesity in the United States parallels the increase in variety and number of high-energy foods available to consumers in the U.S. food market (71). McCrory et al. recently reported that subjects consuming diets associated with a greater variety of vegetables but a lower variety of sweets, snacks, etc. were relatively lean individuals. Conversely, people who consume a high variety of sweets, snacks, condiments, entrées, carbohydrates, and a low variety of vegetables tended to be relatively fat (71). Furthermore, the variety ratio of vegetables to sweets and snacks predicted body fatness in the study subjects and was a more important predictor than dietary fat, energy density, fiber, and energy intake per kilogram bodyweight. This suggests that diets providing a high variety of vegetables and low variety of sweets, snacks, condiments, entrées, and carbohydrates may be important in promoting long-term reduction in food intake and has potential for treatment of overweight and obese individuals.

Adding fruits and vegetables to the diet was explored as a weight loss strategy in a recent study of obese parents with normal weight children (76). The goal of the study was to evaluate the effect of parent-focused behavioral changes on weight changes in families over a one-year period. One group of families increased fruit intake to 2 fruits per day and vegetables to 3 per day while the other group reduced fat and sugar servings to less than 10 per week. The group with increased fruit and vegetable intake had the greatest reduction in percentage of overweight adults. Furthermore, families who increased fruit and vegetable intake also lowered their fat and sugar intake whereas the group that reduced fat and sugar intake did not increase intake of fruits and vegetables. These data support the positive benefits of including fruits and vegetables in weight loss diets and suggest that an effective approach to weight loss might focus on increasing intake of healthy foods rather than emphasizing dietary restriction.

Foods containing dietary fiber have been proposed to slow gastric emptying and favorably impact satiety (77). This results in a sustained feeling of fullness that may reduce overeating (78). Epidemiological studies generally support a role for fiber in bodyweight regulation among free-living individuals consuming self-selected diets (79). Short-term studies of fiber intake and satiety are typically focused on grains as sources of fiber or use isolated fiber supplements [guar, psyllium, pectin, etc., reviewed in (79)]. Although not tested directly, fruits and vegetables, because of their fiber content, would be expected to be positively associated with increased satiety and reduced overall energy intake.

Longevity

Osler et al. recently reported an association between diet and longevity in a random group of nearly 6,000 men and women living in Denmark and followed for 15 years (80). They found that the diet patterns associated with the lowest all-cause and cardiovascular mortality were diets with frequent intakes of whole grain bread, fruits, vegetables, and fish.

A 26-year prospective study of men in Sweden provided evidence that fruit intake may be associated with greater longevity (81). Cardiovascular death as well as total mortality was higher among men with a low fruit intake compared to men with a high fruit intake. There was no relation between vegetable consumption and mortality or other major diseases. However, separate analysis for different cancers showed fewer ventricular cancers among men who reported higher vegetable intake. Survival analyses were conducted for data at 16 years and 26 years of follow-up. At 16 years (average age of subjects = 70 years) low fruit consumption was independently associated with a higher mortality rate as well as smoking, hypertension, and high serum cholesterol. However, at 26 years (average age of subjects = 80 years), the protective association with fruit was no longer statistically significant.

Bone Health

Hip fractures associated with osteoporosis result in approximately 300,000 hospital admissions and an estimated $9 billion annually in the United States (82). Calcium and vitamin D are well established as important nutrients associated with bone metabolism but less is known about the effect of other nutrients and dietary constituents on bone health.

In 1999, Swiss researchers fed vegetable mixtures containing lettuce, tomato, cucumber, onion, and several herbs to rats for 4 weeks and found a significant reduction in bone resorption (83). Onion feeding improved bone mineral content, density, and cortical thickness by 14-18%. In ovariectomized rats (a model of estrogen withdrawal similar to menopause), onion intake attenuated the hormone-mediated bone resorption in a dose-dependent manner. The investigators suggested that the effect of onion on acute bone resorption was comparable to that of calcitonin (83). It is not clear what specific compounds in vegetables might account for these observations. Some investigators have speculated that phenolic compounds, including quercetin derivatives, may be important in inhibiting bone loss in ovariectomized rats (84), although this has been debated (85).

Two cross sectional studies of human subjects have suggested that fruit and vegetable consumption may contribute to the maintenance of bone density. In a recent study of elderly men and women in the Framingham Heart Study, fruit and vegetable intake was positively associated with bone mineral density at three out of four sites in the hip and forearm of men and two sites in women (86). In the same subjects followed for four a year period, higher intake of fruits and vegetables was associated with less decline in bone mass at one hip site in men, but not in women. This study showed a strong correlation between potassium and magnesium intake and bone density suggesting that fruits and vegetables may play a role in bone health due to their content of these two micronutrients. Potatoes, orange juice, bananas, and tomatoes were among the top 6 sources of potassium for these subjects; bananas and orange juice were among the top 6 foods providing magnesium.

"...In a recent study of elderly men and women in the Framingham Heart Study, fruit and vegetable intake was positively associated with bone mineral density at three out of four sites in the hip and forearm of men and two sites in women."

A cross-sectional study of 62 healthy women (45-55 years) in the United Kingdom demonstrated that several nutrients found in fruit and vegetables predicted bone mineral density as well as markers of bone metabolism (87). Women in the highest quartile of potassium and magnesium intake had significantly lower excretion of pyridinoline and deoxypyridinoline, two urinary markers of bone resorption. There was no significant association between specific foods or nutrient intake and bone mineral density in lumbar spine and hip. However, women who reported having high intakes of fruits during childhood tended to have higher femoral neck bone mineral density than women with low intakes, although the authors admit that these data are subject to recall bias. Mean bone mineral density of forearm was significantly greater with a higher intake of potassium, magnesium, fiber, and alcohol compared to women with lower intake of each of these.

The mechanism for a potential protective effect of fruit and vegetables on bone health is not clear. It has been proposed that a diet favoring alkaline ash, (including fruits, vegetables, vegetable protein, potassium, and magnesium) might decrease the rate of bone attrition by decreasing the need for bone mineral as a buffer for acid load from mixed diets (86).

In conclusion, current available data suggest that there may be a link between bone health and fruit and vegetable consumption, although further investigation is needed to confirm the mechanisms and specific constituents in fruits and vegetables that might account for the association.

Aging and Cognition

Aging is associated with a decline in neuronal function as well as physical and behavioral changes (88). The etiology of neuronal loss with aging is not fully understood, but it is hypothesized that enhanced vulnerability to oxidative stress is an important factor (89). There is increasing interest in the potential of antioxidant nutrients and flavonoids in fruits and vegetables to attenuate the effects of aging.

Early studies suggested that plasma levels of antioxidant nutrients including vitamin E, ascorbic acid, and ß-carotene might be associated with memory performance in elderly human subjects (90, 91). While this work suggests that food sources of these nutrients may also affect memory and cognitive processes, there have been no direct tests of fruit and vegetable intake in humans.

Experiments in rats have shown that fruit and vegetable supplementation can delay the effects of aging on indices of neuronal and behavioral function that are sensitive to oxidative stress (88, 92). Joseph et al. provided extracts of strawberry, spinach, or vitamin E supplements to rats over a long-term period from adulthood (6 months) to middle age (15 months). The study was designed so that the amount of fruit extracts and vitamin E provided identical antioxidant activity. Rats fed the three dietary supplements had better outcomes on several tests related to cognition (spatial learning and memory), neuronal function, and oxidative stress compared to the control rats. The spinach supplement had the greatest effect on retarding the age-related effects (88). These studies suggest that dietary intervention may prevent the onset of deleterious effects of aging on neuronal and cognitive behavioral function. Furthermore, because the diets were supplemented based on equal antioxidant activity, the differential effects observed between strawberries and spinach suggest the protection was due to properties other than the antioxidant potential of the extracts.

"...It is likely...future research will be directed at determining if fruit and vegetable consumption can delay or prevent age-related decline in cognition, behavior, and neuronal function in humans."

The same research group conducted additional studies in rats to determine if dietary supplementation could reverse age-related and behavioral dysfunction (92). In this study, supplements of blueberry, spinach, and strawberry were fed for an 8-week period to aged rats. Using tests similar to those in the earlier study, they found that the supplements had a positive affect on several parameters of neuronal and behavioral function. The blueberry supplement had the greatest effect on reversing most of the age-related parameters and was the only supplement to induce a reversal in age-related motor deficits.

Aged garlic extract has been shown to increase life span and improve learning in a unique mouse model of normal aging (the senescence accelerated mouse or SAM) [reviewed in (93)]. Red bell pepper had beneficial effects on memory and acquisition performance in this model.

A number of investigators are conducting further studies to define the mechanisms and compounds in fruits and vegetables that account for the observed protective effects (94). It is likely that this will be an intensive area of study and that future research will be directed at determining if fruit and vegetable consumption can delay or prevent age-related decline in cognition, behavior, and neuronal function in humans.

Neurodegenerative Diseases

Neurodegenerative diseases such as Alzheimer's and vascular dementia share, in part, similar etiology to and risk factors for CVD, including oxidative stress (95). It has been proposed that antioxidants, including polyphenols present in fruits and vegetables, might have a protective effect on vascular dementia and Alzheimer's. *In vitro* studies have shown that flavonoids, found abundantly in fruits and vegetables, protect rat neuronal cells from oxidative stress (96).

Dietary intake of flavonoids may be associated with reduced risk of dementia. In a cohort of 1,367 men and women followed for 5 years in southern France, dietary intake of flavonoids was inversely related to risk of dementia (95). Fruit (35.2% of total intake) provided the majority of flavonoids, while vegetables provided 19.1% of flavonoids. Wine and tea were the other major dietary sources. One major limitation to this study is that some important vegetable sources of flavonoids (e.g. onions) were not included in the dietary assessment. Nevertheless, there was a 51% reduction in relative risk for dementia between the second and third tertile of flavonoid intake compared to the lowest intake.

Vitamin C and vitamin E intake may provide protection against Alzheimer's. Plasma levels of vitamin C were found to be 30-60% lower in patients with moderate to severe Alzheimer's disease, respectively, in spite of comparable dietary intake of vitamin C (97). Vitamin C intake and plasma levels have been correlated with cognition performance in healthy aging subjects (98). The reduced plasma levels in Alzheimer's patients may indicate an increase in oxidative stress resulting from the disease although there is much work to be done in this area.

Skin Health and Wrinkling

Oxidative damage to skin is associated with skin aging and wrinkling. A recent cross-sectional study showed that a high intake of vegetables was significantly correlated with reduced skin wrinkling on the hands of 453 elderly subjects of different ethnicity (99). Other foods associated with reduced skin wrinkling included olive oil and legumes. The authors speculated that this combination of foods might be associated with reduced skin damage due to the antioxidants present in these foods. Among the ethnic populations there were differences in the associations between specific food items and the degree of skin wrinkling. The results of this study are intriguing although much further investigation is needed to determine the relationship between diet and skin health.

The following sections were prepared by Mary Ann S. Van Duyn, Ph.D., M.P.H., R.D. and appeared in *Year 2000 Dietary Guidelines – The Case for Fruits and Vegetables First, A Scientific Overview for the Health Professional,* Produce for Better Health Foundation, 1999.

Diverticulosis

Diverticulosis was tagged the "byproduct of our refined eating habits" in a recent Mayo Clinic Health Letter (100). It is found predominantly in industrialized nations and is one of our most common medical conditions. An estimated one-third of people at age 50 have diverticulosis, and this increases to two-thirds of those over 80 years (101). Thus, diverticulosis is clearly linked with aging and its prevalence had been increasing among Western populations over the years.

Diverticulosis occurs when small, out-pouches called diverticulum develop in the large intestine or colon. In most cases, this condition is asymptomatic; only an estimated 10-25% of affected individuals become symptomatic (102). Symptoms develop when the colonic diverticulum and surrounding tissues become inflamed, frequently as the result of obstruction by dietary products or stool. This inflammation of the diverticulum is called diverticulitis. Afflicted individuals experience abdominal pain, fever, and tenderness upon examination, and, if left untreated, diverticulitis can result in perforation, or tearing, and inflammation of the abdominal wall.

"...Diverticulosis was tagged the 'byproduct of our refined eating habits' in a recent Mayo Clinic Health Letter...An estimated one-third of people at age 50 have diverticulosis, and this increases to two-thirds for those over the age of 80 years... High fiber diets...are now known to provide the best defense against the development of diverticulosis."

High fiber diets, which help to increase stool bulk and moisture, and reduce travel time through the gastrointestinal tract, are now known to provide the best defense against the development of diverticulosis. This role for diet in the prevention of diverticulosis came first from the epidemiological data. People in less industrialized countries with higher fiber diets were observed to be at much lower risk for diverticulosis than people from industrialized nations, with diets rich in milled flour, refined sugar, and meat (103). Subsequently, data from numerous animal and clinical studies have confirmed and strengthened the science base supporting a protective role for high fiber diets in diverticulosis development. (104, 105).

Insoluble fiber may be the type of dietary fiber most responsible for this protective role. Recent prospective work by Aldoori and colleagues found that insoluble fiber, and particularly cellulose, was significantly associated with decreased risk for diverticulosis among a large group of male health professionals (n=43,881 men) (106). Earlier work by these same researchers identified an association between the fiber from fruits and vegetables, not cereal sources, and reduced risk of diverticulosis (107)

Fruits and vegetables are known generally to be higher in cellulose, one type of insoluble fiber, than cereals (108). Aldoori and colleagues thought that the higher cellulose in fruits and vegetables, compared with cereals, may explain the association between the fiber from fruits and vegetables, and lower risk of diverticulosis (107). This latest work suggests it is the insoluble fiber that is providing the protective benefit in diverticulosis and particularly the cellulose component in the insoluble fiber.

Work by Marlett conveniently identifies amounts of insoluble fiber in our diets, including that from fruits and vegetables (108). Cellulose accounted for 30% of the insoluble fiber in fruits and 50% or more in vegetables. Most foods contain about a third or less (30% or less) of the total fiber from cellulose, with the exception of legumes which is about half.

Taken together, these results highlight an opportunity to more widely promote the fact that fruits and vegetables provide dietary fiber; and that the insoluble fiber, and especially the cellulose, in fruits and vegetables maybe particularly important in helping prevent diverticulosis.

Arthritis

An austere vegetarian dietary regime has proven beneficial for some patients with rheumatoid arthritis. In a controlled clinical trial of 53 patients with rheumatoid arthritis, significant subjective and objective improvement was observed for patients who followed a lacto vegetarian diet compared to controls at a one-year follow-up (109). Of note however, is a high dropout rate (35%) due to worsening of arthritic symptoms. At the end of two years, a group of these same patients continued to benefit from adhering to the lacto vegetarian diet (110). An uncooked, lactobacilli-rich, vegan diet has also provided subjective improvement to some patients with rheumatoid arthritis. It is proposed that changes in the intestinal flora, due to these dietary regimes, may play a role in rheumatoid arthritis (111).

Intriguing as these results are, it is too early to say anything definitive about a potential role for fruits and vegetables, as part of a vegetarian diet for arthritis. A watching brief is the most prudent approach.

Birth Defects

Neural tube birth defects occur when the neural tube – which eventually becomes the spinal tube – fails to close about three to four weeks after an egg is fertilized by sperm (112). When the neural tube fails to close toward the bottom, the child is born with spina bifida. If the problem occurs towards the top of the neural tube, the child is born without a brain (anencephaly), and usually dies soon after birth.

It is now proven that folic acid, a water-soluble B vitamin, can prevent neural tube defects such as spina bifida. The most substantial evidence comes from a randomized double-blind prevention trial in which folic acid showed a 72% protective effect in 1,817 women at high risk of having a pregnancy with a neural tube defect (113). Supporting evidence from a number of epidemiological studies is also available (114, 115), including one case-control study that found low dietary folate intake to be a risk factor for neural tube defects (116).

Scientific experts now estimate that half of all neural tube defects could be prevented if women were to consume the recommended intake of folic acid shortly before they conceive. Recommended intakes are 0.4 mg or 400 micrograms of folic acid a day for all women of childbearing age who are capable of becoming pregnant.

"...Scientific experts now estimate that half of all neural tube defects could be prevented if women were to consume the recommended intake of folic acid shortly before they conceive... Folic acid containing fruits and vegetables, along with fortified grain products, can play a vital role in meeting folic acid recommendations to prevent neural tube defects."

In the United States alone, about 2,500 infants are born each year with spina bifida and anencephaly, and about 1,500 fetuses affected with these birth defects are aborted each year (117). The medical and emotional costs of having and raising a child with these disorders are enormous.

Although we now know that adequate folic acid intakes can prevent neural tube defects, the mechanisms responsible are not yet fully understood. Sources of folic acid from fruits and vegetables in our diet include green leafy vegetables, oranges, and orange juice, and dried beans such as pinto and navy. Beginning in 1998, U.S. grain products are being fortified with 430 to 1,400 micrograms of folic acid per pound of food item, providing us with an additional source of dietary folic acid.

Estimated daily intakes of folic acid, before fortification, fall short of dietary recommendations for women of childbearing age. However, recent work by Firth and colleagues suggest that women of childbearing age can achieve daily intakes of 400 micrograms, without supplementation, now that fortification is in place (118). This suggests that folic acid containing fruits and vegetables, along with fortified grain products, can play a vital role in meeting folic acid recommendations to prevent neural tube defects. Although the folic acid naturally occurring in fruits and vegetables is not as readily available as that in fortified foods or supplements, an important opportunity exists to more widely promote this health benefit of fruits and vegetables as one way to better insure adequate folic acid intakes.

Cataracts

A unique, relatively new protective role for fruits and vegetables is in cataract prevention. Cataracts occur when the lens of the eye is unable to function due to opacities. Lens opacities develop when proteins in the eye are damaged by photo-oxidation; these damaged proteins build up, clump, and precipitate. The result is diminished vision due to cloudiness and discoloration, and if left untreated, eventual blindness. First line defense systems protecting the initial oxidative stress are believed to be antioxidants such as vitamin C and carotenoids, found widely in fruits and vegetables.

Cataracts are one of the world's major causes of blindness, with an estimated 50 million people in the world being blind due to them (119). Cataracts are most common among the elderly. Occurrence in the U.S. increases from 5% at age 65 years to 40% for persons 75 years and older (120). Health care costs associated with cataracts among the elderly are significant. In the United States, age-related cataracts cost $5 billion/year, which is the largest single item in Medicare expenditures, and accounts for 1.2 million cataract extractions per year (121).

"...A unique, relatively new protective role for fruits and vegetables is in cataract prevention...First line defense systems protecting the initial oxidative stress are believed to be antioxidants such as vitamin C and carotenoids, found widely in fruits and vegetables."

It is estimated that over half of cataract extractions and associated costs would be eliminated if cataracts could be delayed ten years. Substantial evidence suggests that consuming high levels of antioxidants – vitamin C and carotenoids – are associated with delayed development of the various forms of cataracts. There is growing epidemiological evidence that that same beneficial relationship exists for fruits and vegetables.

The case for a protective role of fruits and vegetable on cataract development begins with case-control studies, such as the one by Jacques and Chylack (122). In this first, and perhaps most important study, high fruit and vegetable intake was associated with lower risk of any form of cataracts. These investigators found a significant five-fold reduction in relative risk for cataracts among consumers of more than 1.5 daily servings of fruits, vegetables, or both fruits and vegetables. Mares-Perlman and associates followed with a cohort study. In this study of middle-aged and older residents of Beaver Dam, Wis., dietary sources of fiber and carotenoids were associated with lower risk for cataracts, particularly in men (123). However, a recent cohort study by Hankinson and colleagues, of women 45 to 67 years of age, found high dietary carotenoid intake associated with lower risk for cataract extraction (124). High consumers of carotenoids were noted to have a 39% lower risk for cataract extraction compared with low consumers. Most recently, a Harvard based study of U.S. male health professionals found beta-carotene rich foods (such as spinach, broccoli, corn, and tomato sauce) associated with a significantly lower risk of cataracts (125).

As the science base continues to strengthen, the data presently available were sufficiently convincing for Taylor and Colleagues to conclude in the American Journal of Clinical Nutrition that "optimizing nutriture, including diets rich in fruits and vegetables, may provide the least costly and most practical means to delay cataract"(120).

Conclusion

The most convincing data for a relationship between fruit and vegetable intake and disease prevention would be provided by large randomized trials or intervention studies providing fruits and vegetables to defined populations for a period of time and assessing health-related outcomes. Because of the multi-factorial etiology and the prolonged time course of disease onset, such trials have not been conducted. However, small clinical studies have looked at the effect of fruit and vegetable intake on risk factors and intermediate endpoints (biomarkers) for disease. These investigations add important data to existing case-control and prospective data.

Collectively the current evidence supports a significant association between fruit and vegetable intake and health. Current trends toward the development and use of new biomarkers for disease should allow for larger and improved studies and exciting new work to improve our understanding of the mechanisms by which fruits and vegetables might improve human health. In the meantime there are ample scientific data to support a dietary guideline goal of consuming 5-10 servings of fruits and vegetables each day. The data also strongly suggest that increasing fruit and vegetable consumption could have significant positive effects on improving the health of the nation.

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FRUITS & VEGETABLES

Report Card of Health Benefits

Condition	Strength of Evidence	Assessment of Evidence
Cancer	Substantial for some sites	Convincing for many cancers
Cardiovascular Disease	Growing use of biomarkers	Convincing
Hypertension	Few diverse trials	Convincing as adjunct
Stroke	Growing	Promising
COPD and Lung Function	Growing	Highly suggestive
Diabetes	Limited	Potential, plausible mechanisms
Obesity	Sparse direct data	Convincing as adjunct
Longevity	Limited	Plausible
Bone Health	Few human studies	Plausible
Aging and Cognition	Few human studies	Plausible
Neurodegenerative Disease	Limited human data	Plausible
Skin Health and Wrinkling	Sparse	Watching
Diverticulosis	Strong	Convincing
Arthritis	Sparse	Watching
Birth Defects	Substantial, proven	Most convincing
Cataracts	Needs clinical trial	Suggestive

FRUITS & VEGETABLES

Active Compounds in Fruits and Vegetables and Associated Condition

Antioxidants, including vitamin C, ß-carotene, carotenoids, flavonoids	Cancer, Heart Disease, including Stroke, Cataracts, Aging, Neurodegenerative Disease, Skin Wrinkling
Folate	Birth Defects Cancer Heart Disease
Fiber Soluble Insoluble	 Heart Disease, Diabetes Diverticulosis
Potassium	Stroke Hypertension Bone Health
Magnesium	Bone Health
Low Fat/Low Energy Food	Obesity

Produce Nutrition

		Serving Size (g)	Total Calories	Calories From Fat	Total Fat (g)	Sodium (mg)	Potasium (mg)	Total Carbohydrate (g)	Dietary Fiber (g)	Sugars (g)	Protein (g)	% DV Vitamin A*	% DV Vitamin C	% DV Calcium	% DV Iron
Apple	1 medium	154	80	0	0	0	170	22	5	16	0	2	8	0	2
Artichoke	1 artichoke	56	25	0	0	70	180	6	3	1	2	2	10	2	2
Asparagus	5 spears	93	25	0	0	0	230	4	2	2	2	10	15	2	2
Avocado	1/5 medium	30	55	45	5	0	170	3	3	0	1	0	4	0	0
Banana	1 medium	126	110	0	0	0	400	29	4	21	1	0	15	0	2
Bell Pepper	1 medium	148	30	0	0	0	270	7	2	4	1	8	190	2	2
Blueberries	1 cup	140	100	10	1	0	105	27	3	11	1	0	15	0	2
Broccoli	1 medium stalk	148	45	0	.5	55	540	8	5	3	5	15	220	6	6
Brussels Sprouts	4 sprouts	84	40	5	.5	25	290	6	3	2	2	8	120	2	0
Cantaloupe	1/4 medium	134	50	0	0	25	280	12	1	11	1	100	80	2	2
Carrot	7" long	78	35	0	0	40	280	8	2	5	1	270	10	2	0
Cauliflower	1/6 medium	99	25	0	0	30	270	5	2	2	2	0	100	2	2
Celery	2 medium	110	20	0	0	100	350	5	2	0	1	2	15	4	2
Cherries	21 cherries; 1 cup	140	90	0	.5	0	300	22	3	19	2	2	15	2	2
Collards	2 cups chopped	72	25	0	0	30	25	5	1	2	1	50	30	2	0
Cucumber	1/3 medium	99	15	0	0	0	170	3	1	2	1	4	10	2	2
Figs (dried)	2 figs	38	100	0	0	5	230	23	3	25	1	0	0	4	2
Grapefruit	1/2 medium	154	60	0	0	0	230	16	6	10	1	15	110	2	0
Grapes	1 1/2 cups	138	90	10	1	0	270	24	1	23	1	2	25	2	2
Green Beans	3/4 cup	83	25	0	0	0	200	5	3	2	1	4	10	4	2
Green Cabbage	1/12 medium head	84	25	0	0	20	190	5	2	3	1	0	70	4	2
Green Onion	1/4 cup chopped	25	10	0	0	5	70	2	1	1	0	2	8	0	0
Honeydew Melon	1/10 medium	134	50	0	0	35	310	13	1	12	1	2	45	0	2
Iceberg Lettuce	1/6 medium head	89	15	0	0	10	120	3	1	2	1	4	6	2	2
Kiwifruit	2 medium	148	100	10	1	0	480	24	4	16	2	2	240	6	4
Leaf Lettuce	1 1/2 cups shredded	85	15	0	0	30	230	4	2	2	1	40	6	4	0
Lemon	1 medium	58	15	0	0	5	90	5	1	1	0	0	40	2	0
Lime	1 medium	67	20	0	0	0	75	7	2	0	0	0	35	0	0
Mango	1/2 mango	104	70	5	.5	0	125	17	1	15	0	40	15	0	0
Mushrooms	5 medium	84	20	0	0	0	300	3	1	0	3	0	2	0	2
Mustard Greens	1 1/2 cups chopped	84	25	0	0	40	230	3	1	1	2	90	100	0	0
Nectarine	1 medium	140	70	0	.5	0	300	16	2	12	1	4	15	0	2
Onion	1 medium	148	60	0	0	5	240	14	3	9	2	0	20	4	2
Orange	1 medium	154	70	0	0	0	260	21	7	14	1	2	130	6	2
Peach	1 medium	98	40	0	0	0	190	10	2	9	1	2	10	0	0
Pear	1 medium	166	100	10	1	0	210	25	4	17	1	0	10	2	0
Pineapple	2 slices	112	60	0	0	10	115	16	1	13	1	0	25	2	2
Plums	2 medium	132	80	10	1	0	220	19	2	10	1	6	20	0	0
Potato	1 medium	148	100	0	0	0	720	26	3	3	4	0	45	2	6
Prunes	5 prunes	42	110	0	0	0	280	25	3	18	1	10	2	2	4
Radishes	7 radishes	85	15	0	0	25	230	3	0	2	1	0	30	2	0
Raisins	1/4 cup	40	130	0	0	10	310	31	2	29	1	0	0	2	6
Raspberries	1 cup	125	50	0	0	0	160	17	8	12	1	0	40	2	2
Romaine Lettuce	6 leaves	85	20	0	.5	0	140	3	1	2	1	20	4	2	2
Spinach	1 1/2 cup shredded	85	40	0	0	160	130	10	5	0	2	70	25	6	20
Strawberries	8 medium	147	45	0	0	0	270	12	4	8	1	0	160	2	4
Summer Squash	1/2 medium	98	20	0	0	0	260	4	2	2	1	6	30	2	2
Sweet Corn	1 medium ear	90	80	10	1	0	240	18	3	5	3	2	10	0	2
Sweet Potato	1 medium, 5"long, 2" diameter	130	130	0	0	45	350	33	4	7	2	440	30	2	2
Tangerine	1 medium	109	50	0	.5	0	180	15	3	12	1	0	50	4	0
Tomato	1 medium	148	35	0	.5	5	360	7	1	4	1	20	40	2	2
Watermelon	1/18 medium melon; 2 cups diced	280	80	0	0	10	230	27	2	25	1	20	25	2	4

Percent daily values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

Source: U.S. Food and Drug Administration and Produce Marketing Association fruits and vegetables

EAT 5 A DAY for better health

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