



AMERICA'S PHYTONUTRIENT REPORT

HEART HEALTH BY COLOR

Executive Summary

Based on the five color groupings of phytonutrients reported in *America's Phytonutrient Report: Quantifying the Gap*, on average, 8 out of 10 Americans (76%) have a “phytonutrient gap”. The “phytonutrient gap” referred to in the report was defined as the percentage of the population with phytonutrient intakes less than the median intake (“prudent intake” or PI) by adults who meet recommended daily intakes of fruits and vegetables based on established government guidelines. In other words, the “gap” represents the shortfall of phytonutrient intakes based on a typical level of phytonutrient intake consistent with a diet that is considered to have a prudent amount of fruits and vegetables.

More specifically, Americans are falling short, meaning they have intakes below the PI, in virtually every color category of phytonutrients:

- ▶ 69% fall short in green
- ▶ 74% fall short in red
- ▶ 83% fall short in white
- ▶ 76% fall short in purple/blue
- ▶ 80% fall short in yellow/orange

There is a global burden of poor health attributable to low consumption of fruits and vegetables. This extension report entitled *America's Phytonutrient Report: Heart Health by Color* explores the “phytonutrient gaps” and key phytonutrient food sources that research suggests are important contributors to heart health. Using NHANES and USDA data, comparisons of phytonutrient intakes and sources between the subpopulation of adults who meet their fruit and vegetable recommended intakes (“meeters”) and those who do not (“non-meeters”) are explored. Biological measures including blood pressure and body mass index, two factors closely related to heart disease risk, are compared between “meeters” and “non-meeters”.

While there are thousands of phytonutrients and many may contribute to heart health through a variety of mechanisms, this report focuses on four phytonutrients (allicin, quercetin, anthocyanidins and resveratrol) that fall into two color groupings (white and purple/blue) which research points to as potentially important to heart

health. For the purposes of this report, the “cardio phytonutrient gap” represents the shortfall of the heart-healthy phytonutrient intakes based on a typical level (the median) of phytonutrient intake consistent with a “prudent diet”. Essentially, the “cardio phytonutrient gap” is analogous to the “phytonutrient gap”, but includes just four phytonutrients of interest rather than the fourteen included in *America's Phytonutrient Report: Quantifying the Gap*.

Key findings from the present analyses include:

- ▶ Only 2 out of 10 Americans consume “prudent intake” levels of select heart-healthy phytonutrients, which means 80% of Americans have a “cardio phytonutrient gap”
- ▶ Key concentrated food sources for heart-healthy phytonutrients include garlic for allicin, onion for quercetin, blueberries for anthocyanidins and red grapes for resveratrol
- ▶ “Meeters” and “non-meeters” tend to consume the same food sources of phytonutrients in roughly the same proportions, but “meeters” consume greater quantities of the most phytonutrient-rich foods within a color category
- ▶ Consistent with research, “non-meeters” appear to have poorer health status as measured by prevalence of high blood pressure and obesity compared to “meeters”
- ▶ Closing the “cardio phytonutrient gap” with plant-based foods from the white and purple/blue categories of the phytonutrient spectrum is advisable to promote better heart health

Overall, consuming a wide variety of phytonutrient-dense whole fruits and vegetables is the primary goal. Beyond this, a plant-based dietary supplement which includes heart-healthy phytonutrients such as allicin, quercetin, anthocyanidins and/or resveratrol is an option for those wishing to fill their “cardio phytonutrient gap” in order to promote better heart health.

Introduction

According to data from the American Heart Association, every 25 seconds an American will suffer a coronary event, and about every minute someone will die from one. Heart disease is the single largest killer of American adults.¹

Substantial research has demonstrated the heart health benefits of eating a dietary pattern high in fruits and vegetables.^{2,3} Nutritionally, fruits and vegetables are lower calorie sources of key nutrients, such as potassium, dietary fiber, folic acid, and vitamins A, C and E. They also contain literally thousands of naturally-occurring compounds referred to as phytochemicals or phytonutrients, which may have health benefits beyond basic nutrition.

Unfortunately, recent data from *America's Phytonutrient Report: Quantifying the Gap*⁴ indicate that based on the five color groupings of phytonutrients used in that analysis, on average, 8 out of 10 Americans (76%) have a "phytonutrient gap" – that is, they fall short in consuming key phytonutrients from plant-based foods that could benefit their health. Related research indicates that less than 1 in 10 Americans meet their calorie-specific MyPyramid fruit or vegetable recommendations.⁵ Further, the fruit and vegetable choices by those meeting the recommendations are not typically the most nutrient-dense or phytonutrient-rich options. The single largest contributor to overall fruit intake in the current American diet is orange juice and white potatoes for vegetables.⁵

There is a global burden of poor health attributable to low consumption of fruits and vegetables.⁶ This extension report entitled *America's Phytonutrient Report: Heart Health by Color* explores the "phytonutrient gaps" and key phytonutrient food sources for four of the phytonutrients that research suggests are important contributors to heart health. Biological measures including blood pressure and body mass index, two factors closely related to heart disease risk, are compared among "meeters" and "non-meeters".

The "Phytonutrient Gap" Defined

America's Phytonutrient Report: Quantifying the Gap looked at 14 select phytonutrients including carotenoids (alpha-carotene, beta-carotene, beta-cryptoxanthin, lutein/zeaxanthin, lycopene), flavonoids (anthocyanidins, epigallocatechin 3-gallate (EGCG), hesperitin, quercetin), phenolics (ellagic acid, resveratrol), isothiocyanates, isoflavones and allicin in order to determine gaps in consumption.

Because phytonutrients are not considered "essential" to human health, there are no Dietary Reference Intakes (DRIs), as there are for macro and micronutrients. The original report was not designed to establish DRIs for phytonutrients, nor does it claim to establish phytonutrient intake recommendations associated with optimal or even better health. Rather, using NHANES and USDA datasets,⁷⁻¹¹ the report identified the median intakes of phytonutrients by the subpopulation of adults who meet recommended daily intakes of fruits and vegetables ("meeters"). The median intake was referred to as the "prudent intake" (PI), because that is the intake level among adults eating a "prudent diet" that contains recommended amounts of fruits and vegetables. In the case of isothiocyanate and allicin, the median intakes by "meeters" were zero, so mean intakes were selected as the PI. Following the identification of the PI, the percentage of Americans who failed to meet the PI for each phytonutrient examined was then calculated to determine the percentage of adults who fall short, or have a "gap" in consumption. Taken together, the "phytonutrient gap" was thus defined as the percentage of the American adults with phytonutrient intakes less than the level consumed by those eating a "prudent diet".

The "phytonutrient gap" by color category is listed in Table 1.

Table 1: "Phytonutrient Gaps" by Color Category

COLOR CATEGORY	PHYTONUTRIENT	AVERAGE PERCENT NOT MEETING PI
GREEN	EGCG	69
	Isothiocyanate	
	Lutein/zeaxanthin	
	Isoflavones	
RED	Lycopene	74
	Ellagic Acid	
WHITE	Allicin	83
	Quercetin	
PURPLE/BLUE	Anthocyanidins	76
	Resveratrol	
YELLOW/ORANGE	Alpha-carotene	80
	Beta-carotene	
	Hesperitin	
	Beta-cryptoxanthin	

The “Cardio Phytonutrient Gap”

The “cardio phytonutrient gap” referred to in this extension report specific to heart health is defined as the percentage of the population with phytonutrient intakes less than the median intake (“prudent intake” or PI) for some of the phytonutrients (allicin, quercetin, resveratrol and anthocyanidins) which research suggests contribute to heart health. In other words, the “cardio phytonutrient gap” represents the shortfall of four select heart-healthy phytonutrients based on an average level of phytonutrient intake consistent with a “prudent diet” which is high in fruits and vegetables. It is important to point out that a “prudent diet” may still fall short of desirable or optimal levels of some or even most phytonutrients found in fruits, vegetables and other plant sources including teas and beans. It is also important to point out that the four heart-healthy phytonutrients are not the only phytonutrients that may likely contribute to better heart health and/or better overall health. For the purposes of this report, the “cardio phytonutrient gap” is analogous to the “phytonutrient gap”, but includes four phytonutrients of interest rather than the fourteen included in the original report.

On average 80% of Americans have a “cardio phytonutrient gap”

When it comes to heart health specifically, many people may associate the color red with heart health in part due to several successful marketing campaigns. But, while 74% of Americans have a “phytonutrient gap” in the red color category of phytonutrients, there are larger “phytonutrient gaps” in the two color categories perhaps more critical to heart health – white and purple/blue. For white, the phytonutrients of interest include allicin and quercetin, and 83% of Americans are falling short on these phytonutrients. For purple/blue, the phytonutrients of interest include anthocyanidins and resveratrol, and 76% of Americans are falling short on these phytonutrients. On average then, based on the heart health specific color groupings of white and purple/blue, 80% of Americans $([83\% + 76\%]/2)$ have a “cardio phytonutrient gap”. This means, on average, only 2 out of 10 Americans consume levels of select heart-healthy phytonutrients from foods consistent with a “prudent diet”.

Methodology & Data Sourcing

As previously stated, these analyses utilize publicly available data from NHANES and USDA. A total of 8072 adults age 19 years and older in the survey period 2003-2006 provided 2 complete days of dietary recalls. The most recent USDA flavonoid database was used to estimate concentrations of anthocyanidins and quercetin in foods, and data from the published literature were used to estimate food concentrations of resveratrol and allicin. Estimates of intake of all the phytonutrients were limited to the food forms (i.e., raw, cooked, canned) for which the phytonutrient concentration data were determined to be applicable. The analyses in this report utilize 2-day average intakes from dietary recalls, and are not necessarily indicative of long-term intakes. An additional limitation of this study is the small sample size. And finally, these data and corresponding analyses are associations only (not causations) which may point towards a relationship between phytonutrient intake and heart health. Further research is needed in this area of fruit and vegetable consumption and heart health, particularly with respect to dietary patterns, which offer concentrated food sources of the most potent phytonutrients found in foods. Additional discovery research on currently unidentified phytonutrients is equally important to the evolution of this area of investigation.

THE WHITE GROUP

The Surprising Power of White

For the white color category, the following section highlights current research and possible health benefits of allicin and quercetin, including the PI for each and the percent of Americans falling short. In addition, because whole plant-based foods are the best source of phytonutrients in any diet, this report investigates food sources of the select heart-healthy phytonutrients among “meeters” versus “non-meeters”.



Allicin

Research: Much of the research investigating the impact of allicin on heart health has focused on its major food source, garlic. Possible mechanisms of action for heart health promotion include cholesterol and blood pressure reduction as well as prevention of platelet aggregation. A meta-analysis of randomized, controlled human trials concluded that garlic promotes a modest, but significant, reduction in total cholesterol driven mostly by the reduction of the lipoproteins that transport triglycerides; however, there was no appreciable reduction of low-density lipoproteins (“bad cholesterol”) or increase in high-density lipoproteins (“good cholesterol”).¹² In terms of blood pressure, one meta-analysis found that garlic helped to lower blood pressure in hypertensive individuals,¹³ while other research on blood pressure showed mixed effects¹⁴ or no effect among healthy adults.¹⁵ Other mechanistic investigations suggest that allicin potentially offers anti-platelet activity; therefore, it may help prevent platelets from forming clots which are associated with risk of heart disease.^{16,17}

Prudent Intake (PI): The PI for allicin was found to be 0.85 mg/day. Among adults 19 years and older, 15% meet this PI, which means 85% fall short. Females ages 19-44 had the highest percent (18%) of individuals meeting their PI compared to females 65 years and older with the lowest percent (9%) meeting PI levels. This suggests younger females consumed higher levels of garlic compared to other population segments, but the overwhelming majority of all adults consume less than the PI of 0.85 mg.

Food Sources: Allicin is a sulfur compound found in garlic and other members of its plant family. Allicin is formed when alliin comes in contact with the enzyme allinase located in the cellular membrane of the garlic bulb. Allicin is a highly unstable compound and is destroyed by common cooking methods.¹⁸ Consequently, for the purposes of these analyses, intake of this phytonutrient was entirely from uncooked or minimally cooked (i.e., stir fried) garlic. For both “meeters” and “non-meeters” who consumed on average 0.85 mg/day and 0.42 mg/day of allicin respectively, the number one and only food source in the diet was garlic.

Quercetin

Research: Quercetin is a type of plant-derived flavonoid, known as a flavonol. With respect to heart health, the blood pressure lowering effect of quercetin is thought to help explain why a diet rich in fruits and vegetables is associated with lower rates of myocardial infarction and stroke.¹⁹ Daily doses of quercetin (150 mg/day) have been shown effective in reducing systolic blood pressure and plasma concentrations of oxidized low density lipoprotein (“bad cholesterol”) in overweight individuals at high risk for poor heart health.²⁰ In addition to its blood pressure benefits, quercetin may also protect against chronic inflammation often associated with poor heart health. Investigations into the association between flavonoids and C-reactive protein (CRP) – a biomarker for inflammation and related heart disease risk – identified quercetin among those nutrient compounds having a significant, inverse relationship with serum CRP concentrations in adults.²¹

Prudent Intake (PI): The PI for quercetin was found to be 17.9 mg/day. Among adults 19 years and older, 20% meet this PI, which means 80% fall short. Males ages 45-64 years had the highest percent (25%) of individuals meeting their PI compared to younger (19-44 years) and older females (65+ years) among whom only 15% met their PI. This suggests older males consume higher amounts of quercetin-rich foods compared to the other age/sex groups.

Food Sources: Quercetin is found in more concentrated amounts in onions and apples, and also in brewed green and black tea. Among “meeters” in these analyses, onions were the top source of quercetin in the diet. In contrast, among “non-meeters”, tea was the number one plant-based source of quercetin in the diet, not onions. Baking and sautéing onions produces a 7-25% increase in quercetin concentration, while boiling produces an 18% decrease in concentration based on one study.²² Interestingly, when it comes to onions, there is a gradient in flavonoid content (including quercetin) such that the outer layers of a raw onion remain the richest source of flavonoids even after cooking.²³

THE PURPLE/BLUE GROUP

The Heart-Health Story of Purple/Blue

For the purple/blue color category, the following section highlights current research and possible health benefits for anthocyanidins and resveratrol, including the PI for each and the percent of Americans falling short. In addition, because whole plant-based foods are the best source of phytonutrients in any diet, this report investigates food sources of the select heart-healthy phytonutrients among “meeters” versus “non-meeters”.



Anthocyanidins

Health Benefits: Anthocyanidins are classified as flavonoids. While research to date shows differential effects between flavonoid subclasses and foods, a review of 133 trials suggests flavonoid-rich foods may help lower blood pressure and cholesterol levels.²⁴ In terms of a mechanism, flavonoids have been shown to promote dilation of the blood vessels by stimulating the release of endothelial nitric oxide.²⁵ Flavonoids have also been shown to modulate proinflammatory gene expression, thereby dulling the inflammatory response.²⁶ Related research specific to anthocyanidins shows they inhibit the oxidation of low-density lipoproteins (“bad cholesterol”), which in turn can help prevent atherosclerosis.²⁷ Taken together, anthocyanidins, a subclass of flavonoids, appear to have several potential modes of action that may benefit heart health.

Prudent Intake (PI): The PI for anthocyanidins was found to be 22.0 mg/day. Among all adults 19 years and older, 15% meet this PI, which means 85% of Americans fall short. The groups with the lowest percent (11%) meeting their PI were females and males aged 19-44 years, while males and females 65 years and older had the highest percent (21%) meeting their PI. This suggests that older adults consume more anthocyanidins in their regular diet compared to younger adults.

Food Sources: Anthocyanidins are found in grapes, berries, wine and other fruits. The top two food sources for anthocyanidins – grapes and blueberries – both come from the purple/blue category. For “meeters” and “non-meeters” alike, grapes were the number one food source followed by blueberries. Interestingly, berries are a more concentrated source of anthocyanidins; however Americans choose grapes more often which may be the result of availability and/or price. Although grapes and berries are typically consumed uncooked, research indicates that cooking whole blueberries (in stuffed fish) was found to preserve the anthocyanidins, with only 12 to 30 % degradation.²⁸ Similarly, steam cooking has been shown effective in preserving the anthocyanidin content in purple sweet potatoes.²⁹

Resveratrol

Research: For centuries, the French have consumed diets high in saturated fats, and yet they have had relatively low levels of heart disease. It is believed that this “French paradox” is the result of high levels of wine consumption, which translates to what some scientists call “resveratrol-mediated cardioprotection.”³⁰ Wine is made from grapes which contain a large variety of antioxidants including resveratrol. A review of the body of research indicates that resveratrol intake is linked to a reduced risk of morbidity and mortality associated with cardiovascular disease complications.³¹ Resveratrol has been shown to inhibit proinflammatory agents and increase cellular antioxidants in smooth muscle, which may help protect the vascular system from oxidative stress and benefit blood pressure.³² Furthermore, resveratrol appears to help protect the cardiovascular system by inhibiting the expression of cell adhesion molecules.³²

Prudent Intake (PI): The PI for resveratrol, excluding wine, was found to be 8.2 mg/day. Among adults 19 years and older, 32% meet this PI, which means 68% fall short. Females ages 19-44 have the lowest percent (28%) meeting their PI, while females and males 65 years and older have the highest percent (38%) meeting their PI. This suggests older adults consume more resveratrol, excluding wine as a source, in their regular diet than younger adults.

Food Sources: Resveratrol is found in grape skins where it serves as a defense against fungi. The amount of resveratrol in grape skins varies with the variety, geographic origin, and fungi exposure level.³³ Resveratrol is also found in cocoa, dark chocolate and peanuts. Based on these analyses with wine included, the top contributor to total resveratrol intake by “meeters” was grapes with wine second. The reverse was observed among “non-meeters” with wine first then grapes. When wine was excluded however, grapes were the primary source of resveratrol for all individuals. The second source was peanuts, suggesting the importance of nuts and seeds in the diet for heart health in addition to fruits and vegetables.

Food Sources for the Heart-Healthy Phytonutrients

These analyses suggest that for allicin and resveratrol (excluding wine), highly concentrated food sources are also the most consumed food source for “meeters” and “non-meeters” alike (see Table 2). In contrast, for quercetin, a highly concentrated food source (onion) is the number one food source among “meeters,” but not among “non-meeters” whose number one source is tea, which has a slightly lower concentration per serving. In the case of anthocyanidins, the number one food consumed by both “meeters” and “non-meeters” is grapes, though blueberries are a more highly concentrated source of the phytonutrient.

Table 2: Food Source Comparisons

PHYTONUTRIENT	HIGHLY CONCENTRATED FOOD SOURCE	NUMBER ONE FOOD SOURCE AMONG MEETERS	NUMBER ONE FOOD SOURCE AMONG NON-MEETERS
ALLICIN	Garlic	Garlic	Garlic
QUERCETIN	Onion	Onion	Tea
ANTHOCYANIDINS	Blueberries	Grapes	Grapes
RESVERATROL (EXCLUDING WINE)	Grapes	Grapes	Grapes

“Meeters” and “non-meeters” tend to consume the same food sources of phytonutrients in roughly the same proportions, but the key difference is that “meeters” often consume greater quantities of the most phytonutrient-rich foods.

While the overarching goal is to have Americans eat more of all fruits and vegetables, choosing the most phytonutrient-rich options when possible can help to maximize the potential nutritional benefits from fruits and vegetables. Choosing foods with the highest concentrations of phytonutrients on a regular basis is especially important for those individuals who do not consume their recommended number of daily servings (“non-meeters”).

The fewer servings of fruits and vegetables a person eats, the more those limited servings need to consist of the most phytonutrient-rich foods available.



Biological Measures: Blood Pressure and Body Mass Index

In consideration of known risk factors for heart disease, a comparison between “meeters” and “non-meeters” was conducted for both blood pressure and body mass index (BMI). Using standardized blood pressure measurement categories with 140/90 mmHg considered hypertensive,³⁴ the percent of “non-meeters” with high blood pressure was greater in every age/sex category (except younger females) when compared to “meeters” (see Table 3). This is consistent with the strong relationship between a dietary pattern of higher fruit and vegetable consumption and lower blood pressure, and is in keeping with existing data indicating higher intakes of fruits and vegetables promote improved heart health.³⁵

Table 3: Relationship of Hypertension and Fruit and Vegetable Consumption

SUBPOPULATION	PERCENT OF MEETERS WITH HYPERTENSION*	PERCENT OF NON-MEETERS WITH HYPERTENSION**
MALES 19-44 YEARS	4	10
FEMALES 19-44 YEARS	5	2
MALES 45-64 YEARS	10	22
FEMALES 45-64 YEARS	18	23
MALES 65+ YEARS	17	30
FEMALES 65+ YEARS	30	42

*N varies from 28 (males 65+ years) to 75 (females 45-64 years)

**N varies from 398 (females 65+ years) to 1646 (males 19-44 years)

Using standardized body mass index (BMI) measures where BMI ≥ 30.0 is defined as obese by the Centers for Disease Control and Prevention,³⁶ results from the current analysis are consistent with research, namely the prevalence of obesity was higher among those who failed to meet their fruit and vegetable intake recommendations in every category except older males (see Table 4). These data are in keeping with existing research suggesting a relationship between lower body weight and improved heart health.³⁷

Table 4: Relationship of Obesity and Fruit and Vegetable Consumption

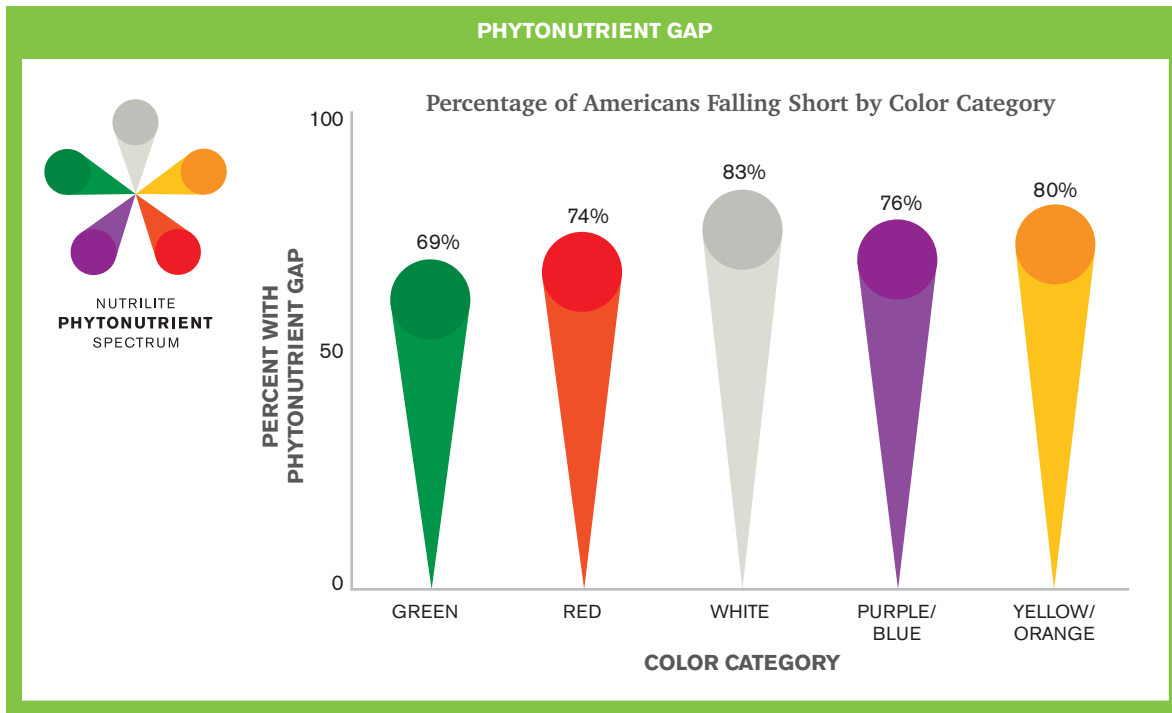
SUBPOPULATION	PERCENT OF MEETERS WHO ARE OBESE*	PERCENT OF NON-MEETERS WHO ARE OBESE**
MALES 19-44 YEARS	26	31
FEMALES 19-44 YEARS	27	31
MALES 45-64 YEARS	21	35
FEMALES 45-64 YEARS	33	39
MALES 65+ YEARS	37	31
FEMALES 65+ YEARS	22	32

*N varies from 59 (females 19-44 years) to 121 (females 45-64 years)

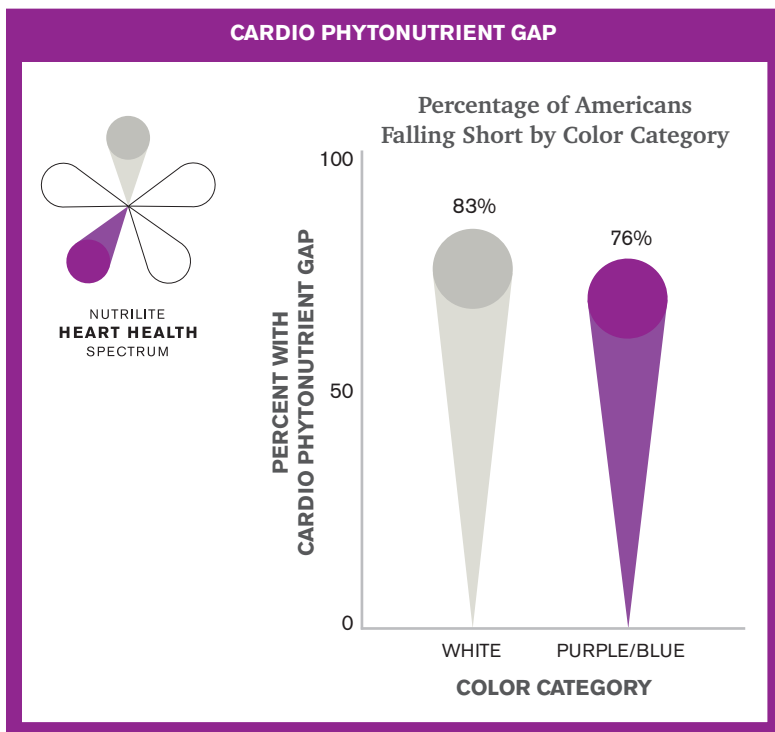
**N varies from 904 (females 65+ years) to 1758 (males 19-44 years)

It must also be noted that individuals who consume more fruits and vegetables are often more likely to lead healthier lifestyles overall (i.e., regular exercise, etc), which would of course have a positive impact on heart health indicators including blood pressure and BMI. With respect to these findings, it must be reiterated that these analyses utilize 2-day average intakes from dietary recalls, and are not necessarily indicative of long-term intakes. An additional limitation of this study is the small sample size. And finally, these data and corresponding analyses are associations only (not causations) which may point towards a relationship between phytonutrient intakes and heart health.

Graph 1: The “Phytonutrient Gap”



Graph 2: The “Cardio Phytonutrient Gap”



Closing the “Cardio Phytonutrient Gap”

As stated in *America's Phytonutrient Report: Quantifying the Gap*, a simple, actionable goal is to have all adults eat two servings from each of the five color categories for a total of ten servings per day of colorful fruits and vegetables. Based on the five color groupings of phytonutrients reported in *America's Phytonutrient Report: Quantifying the Gap*, on average, 8 out of 10 Americans (76%) have a “phytonutrient gap” (see Graph 1).

Based on the heart-health specific color groupings of white and purple/blue, 80% of Americans ($[(83\%+76\%)/2]$) have a “cardio phytonutrient gap” (see Graph 2). For individuals who want to focus on improved heart health in particular, it may be important to consider consuming extra servings of foods from the white and purple/blue categories of the phytonutrient spectrum.

Overall, consuming a wide variety of phytonutrient-dense whole fruits and vegetables is the primary goal. Beyond this, a plant-based dietary supplement which includes heart-healthy phytonutrients such as allicin, quercetin, anthocyanidins and/or resveratrol is an option for those wishing to fill their “cardio phytonutrient gap” in order to promote better heart health.

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