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Colors of fruits and vegetables and diabetes risk in the United States Latino population

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By

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Abstract

Objectives: Fruits and vegetables (FV) play an important role in people's health. The current study aimed analyzed if specific colors of FV are associated with type 2 diabetes mellitus (DM) risk in the United States (US) Hispanic/Latino population.

Methods: This study used participants from the Hispanic Community Health Study/Study of Latinos (HCHS/SOL). It is a multi-center, prospective cohort study with 5,740 self-identified Hispanic/Latino individuals from 2008-2011. Data collected include anthropometrics, oral glucose tolerance test (OGTT), dietary intake, medical history, physical activity, and sociodemographic information. FV are categorized into five color groups: green, white, yellow/orange, red/purple, and uncategorized.

Results: A total 5,740 participants (ages 18-74, BMI 29.5, female 55.2%, US born 21.4%, confirmed DM 13.6%) were included in the analysis. Across all heritage groups (Dominican, Central American, Cuban, Mexican, Puerto Rican, South American, Other/Mixed), the red/purple FV were the least consumed. Higher intake of red/purple FV is associated with lower body mass index (BMI), lower insulin level and higher high-density lipoprotein (HDL) levels. Excluding the uncategorized group, white FV had the highest consumption across all groups. Puerto Ricans consume the least FV compared to other heritage groups. A higher intake of white FV is associated with a higher OGTT glucose and triglyceride levels. Consumption of a higher amount of white FV daily has higher odds of having DM (OR=1.25, p=0.03).

Conclusions: Consuming more white FV may increase odds of having DM. Consuming more red/purple FV may decrease biomarkers associated with DM. Education should focus on varying fruit and vegetable intake and identify causes of low fruit and vegetable intake in Hispanic/Latino groups living in the US.

Introduction

Research over the past few decades has examined the effects of fruit and vegetable (FV) consumption on various diseases. It is well-established FV play an important role in a balanced diet due to the wide array of vitamins, minerals, fiber, and phytochemicals present. Researchers are aiming to determine if FV can lower risk factors or improve clinical outcomes in various chronic diseases (e.g. cancers, diabetes, cardiovascular diseases).

People of Hispanic/Latino (H/L) background are at a higher risk of developing type 2 diabetes mellitus (DM) versus non-Hispanic Caucasians.[1] According to the Centers for Disease Control and Prevention (CDC), the higher risk could be related to specific genes, higher obesity rates, lower physical activity, cultural foods and traditions (i.e. high consumption of calorie-dense foods and pressure to overeat).[1] Currently, there is a gap in the literature examining the role of FV on DM risk factors in the United States (US) H/L population. The present thesis seeks to determine if specific colors of FV have an association on DM risk in the US H/L population.

Literature Review

Diabetes prevalence and the role of acculturation

In the US, the CDC finds the estimated percentage of DM in non-Hispanic White adults to be 10.2% and 18.7% for non-Hispanic Black adults.[2] Among different Hispanic backgrounds in the US, the overall DM prevalence was 16.9%.[2] Within the Hispanic Community Health Study/Study of Latinos (HCHS/SOL) study, diabetes prevalence was 10.2% for South Americans, 13.4% for Cubans, 18% in Puerto Ricans and Dominicans, and 18.3% for Mexicans.[2] Hispanic communities across the US suffer due to low education, low income, lack of diabetes awareness, and low-quality or no health insurance.[2] Research into diabetes prevention in Hispanics becomes more critical due to a 50% risk of developing diabetes compared to only a 40% risk in the US overall.[1] Within the different Hispanic backgrounds, the risk is doubled in Puerto Ricans compared to South Americans in the US.[1]

To find the role of acculturation to the US on the risk of developing DM, a study was done on Latino individuals from NHANES with doctor-diagnosed DM or had a glycated hemoglobin (HbA1C) greater than 6.5%. The researchers assigned an "acculturation score" and found as the level of acculturation increased, so did the risk of DM.[3] Similarly, Schneiderman et al. found DM risk in migrants living in the US for less than five years did not differ significantly with US born H/L. However, DM risk in migrants living in the US for more than ten years was significantly higher than H/L born in the US.[2]

A study involving Hispanic immigrants found the longer an immigrant lives in the US, the higher the association of obesity. The obesity risk was four times higher in residency greater than or equal to fifteen years compared to four or less years. US-born Hispanic individuals had a higher likelihood of obesity than Hispanic migrants. However, the gap in obesity shrinks the longer a migrant lives in the US.[4] The association of obesity and chronic diseases may have a role in development of DM in Hispanics.

While no clear causes were identified as why acculturation increases DM risk, it is believed the physiological stress of acculturating activates the hypothalamic-pituitary axis leading to chronic inflammation and thus, an increased risk of DM.[3] To support the claim, a HCHS/SOL study had individuals without diabetes complete measurements of chronic life stress, physical examination, and an oral glucose tolerance test (OGTT). It was concluded higher chronic stress is related to a higher fasting glucose, increased post-load glucose, and higher HbA1C levels.[5] This means there could be an association of poor glucose regulation and corresponding DM risk in Hispanic individuals. While physiological stress may play a role in disease states, multiple factors must be taken into consideration in designing the study and substantiated in the statistical analysis. To see if this affects specific subgroups differently, national sampling data would need to include subgroups for the different H/L heritages.

Fruit and vegetable dietary patterns in Hispanic/Latino population

Dietary patterns vary across the world. The effects on health, however, can be similar across ethnic groups. A dietary pattern low in processed red meats, sugar-sweetened beverages, diet sodas, and white rice, but high in whole grains, low-fat dairy, fruit, yellow-orange and green vegetables was associated with lower DM biomarkers of inflammation, dyslipidemia, and adipokines. This amounted to a 16-28% lower DM incidence across five ethnic groups.[6] A recent study found animal-based proteins independently increased the risk of developing DM, while the consumption of high-quality vegetable foods may prevent the disease. Furthermore, it was concluded people should limit or entirely discontinue the consumption of animal proteins.[7] A study involving older adults found higher intakes of green vegetables, fruit and berries, oil and margarine, and poultry are predictive of a lower risk of developing T2DM.[8]

In a 2015 study, Colón-Ramos et al. found Puerto Ricans to have the lowest FV consumption when compared to US Hispanics, US Blacks, and US Whites. Overall, US Hispanics have significantly lower FV intake compared to US Black and White individuals.[9] Other validated studies are needed to confirm results. Studies like this are important for identifying any possible links between FV intake and DM for future study. In the New Immigrant Survey, researchers found Hispanic men were more likely than Hispanic women to increase intake of "junk" foods with no increase in fruit intake.[10] As the study was only a survey, caution must be taken in making inferences. The researchers thought it could be related to their socioeconomic status and the lack of available quality food markets.[10]

Diabetes classification and related biomarkers

As diabetes continues to become more prevalent, earlier interventions and better management of the condition grow in importance. The American Diabetes Association (ADA) defines DM as having one or more of the following: HbA1C equal or greater than 6.5%, fasting plasma glucose (FPG) ≥126 mg/dl, OGTT ≥200 mg/dl, or prescribed use of hypoglycemic agents.[2]

In a 2014 study, researchers compared the relationship between HbA1C and glucose in White and Black individuals with diabetes to see if race plays a role in the relationship; it was found not to be statistically different.[11] A study in overweight Latino children at risk of DM found a 2-hr OGTT measuring glucose and insulin a good predictive screening tool for at-risk children.[12] Using the Matsuda index and Homeostasis Model Assessment, researchers tried to establish why Mexican-Americans have an excess incidence of DM compared to US whites. It was found that Mexican Americans had higher levels of glucose, higher family history of DM, higher adiposity, and higher insulin resistance. It was concluded that DM risk in Mexicans comes from a higher insulin resistance and insulin secretion compared to White individuals.[13] In a HCHS/SOL study, researchers examined the FPG, OGTT, and HbA1C on over 15,000 individuals and found over a third of Hispanic adults met at least one or more of the criteria to be diagnosed with prediabetes.[14] As Hispanic individuals are at higher risk for developing DM, it would be very beneficial for them to have their HgbA1C checked at least once or twice yearly by a health care provider.[15]

By identifying effective screening methods and racial/ethnic differences, studies can be developed targeting earlier interventions with FV to evaluate if they can play a role in the prevention of diabetes. Further, studies identifying effective communication channels for the H/L population can play a role in improving care.

Validity of research methods

Before diving deeper into the observations and conclusions of further studies, it is pertinent to understand the methods and validity used to gather the data about FV intake. In the US, the United States Department of Agriculture (USDA) revised its method for better collection of 24-hr food recalls. The automated multiple pass method (AMPM) is a 5-pass method designed to increase reliability by improving methods to keep participant interest and gather better recalls.[16] The increased reliability helps researchers assemble better datasets for analysis. In the HCHS/SOL study, a similar 4-pass method is used to collect the 24-hr food recalls. A consequence of using this method is the reliability of it in long-term studies as individuals' diets change or the recalls do not reflect an individual's typical intake. Another method used in food intake studies are food frequency questionnaires (FFQ). One study tested the usefulness of this method by having adults complete four 24-hr food recalls and an FFQ. It was concluded frequency data can be an important covariate when used with food recalls for estimating usual intake.[17] However, it remains that FFQs are prone to imprecision and reporting bias.[18] Validated FFQs tend to have several response options for each question and offer relevant food items (e.g. an FFQ in a population of Finnish people will have culturally-relevant foods on the questionnaire). Using an FFQ and food recall(s) in a study can help make the data more reliable. Validity on dietary assessment methods used in the European Prospective Investigation into Cancer and Nutrition (EPIC) study were tested. Multiple centers tested the validity of the questionnaire with either twelve monthly 24-hr recalls over a year, multiple food records, or gathering biochemical data as references. It was concluded the repeatability of the questionnaire was good, but the validity was modest to good depending on the testing center. Similar studies are needed due to the overestimating intakes of fruits, vegetables, fat, fish, beta-carotene, and vitamin C.[18]

Classification of fruits and vegetables

Limited research has been done on methods of classifying fruits and vegetables. In addition, many studies use their own classifications. This classification might be by color group, type of FV or antioxidants. By not having universal FV groups, studies may make associations, or no associations based on how the researchers grouped the FV. The present thesis grouped the FV by color and is described further in the methods section.

A study by Pennington and Fisher offers insight on how fruits and vegetables could be grouped in future studies. Based on FV total antioxidant capacity, botanic family, part of the plant, and bioactives, ten groups were established: dark green leafy vegetables, cabbage family vegetables, lettuces, Allium family bulbs, legumes, deep orange/yellow fruits, roots, and tubers, citrus family fruits, tomatoes and other red FV, red/purple/blue berries, and other.[19] Ultimately, researchers will determine if they will develop their own classification for each study, or use a classification system from another study. Mirmiam et al based their FV color groups on the Pennington and Fisher classification system.[19,20] However, the researchers modified their system based on color of the edible portion and to fit their FFQ items.[20] Cömert et al created a FV classification system based on total antioxidant capacity. This system relates FV colors to antioxidant capacity and suggests FV should be classified by low-, medium-, and high-antioxidant groups. This model shows blue, magenta, and red FV are high-antioxidant foods, while green vegetables are low-antioxidant foods.[21] This model would likely be best for studies designed to identify links between FV antioxidant levels and disease risk. There is not sufficient evidence to suggest the best way for researchers to classify FV.

The role of fruits and vegetables on chronic conditions

There have been strong associations between fruit and vegetable intake and cardiometabolic risk, hypertension (HTN), and cancer. The effects FV may have on these conditions may translate to positive outcomes on DM risk.

In Iran, researchers found FV to have associations in both sexes with lower weight gain and abdominal fat, and red/purple FV to have an inverse relationship with weight gain. In males, an inverse relationship in waist circumference with white/green FV and an inverse relationship on weight gain with yellow FV in women was found.[20] Other research has shown a reduced risk of weight gain in individuals consuming a high FV intake.[22]

In the EPIC study, high FV consumption (569 grams or more) was associated with a lower risk of mortality from respiratory, circulatory, and digestive diseases. High intake of raw vegetables was associated with lower risk of death from neoplasms, mental and behavioral disorders, while high fruit intake was associated with a higher risk of death from nervous system diseases.[23] In a study of Chinese adults with no chronic diseases, a higher intake of FV over a long period decreased the risk of HTN.[24]

A longitudinal study in Welsh men concluded FV, especially fruit, could considerably lower the risk of dying from various cancers in middle-aged men.[25] Two case-control studies examined colors of FV on colorectal cancer but came up with contrasting findings. In the first study from 2015 in Chinese adults, it was found orange/yellow, red/purple, and white FV groups had an inverse association with colorectal cancer, while the green FV group had no significant association.[26] In the other study from 2017 in Korea, researchers concluded a high FV intake as well as green and white FV were associated with lower risk in women and similarly in men, but orange/yellow FV was linked to an increased risk in men.[27] The findings from both of these studies agree higher FV intake can reduce risk, but differ in the associations of orange/yellow FV.[26,27] Possible explanations could be the difference in ethnicities, method of matching case-controls, classification of FV, and the accuracy of the FFQ data.

A study evaluating FV intake with risk of major chronic disease with participants from the Nurses' Health study and the Health Professionals' Follow-Up study observed a non-significant slight reduction in chronic disease development with a high FV intake. Among all colors observed, green leafy vegetables were identified as having the strongest inverse relationship for chronic disease.[28]

The role of fruits and vegetables on diabetes

A seven-year study on Chinese adults ages 30-79 found fresh fruit consumption was significantly associated with a lower risk of DM and had a lower risk of complications when individuals with diabetes consume higher amounts of fruit. The researchers suggested clinicians discontinue restricting fruit in individuals with diabetes.[29] Before clinicians follow their suggestion, it would be wise to confirm results with several studies including a randomized control study (RCT) and different methods of collecting dietary intake in individuals with diabetes.

The influence of temperate, subtropical, and tropical fruit consumption on DM showed a high fruit consumption was not associated with a lower risk of DM in older Asians. Temperate fruits like apples were associated with lower risk in women, but high glycemic index (GI) foods like bananas presented a higher risk in men.[30] While the researchers claim high GI fruits are a factor in higher DM risk,[30] research by Muraki et al argues there is not a significant association of high GI foods on DM risk.[31]

Vegetables, but not fruits were associated with a decreased DM risk in Chinese women ages 40-70.[32] The lack of association with fruit on DM risk conflicts with the results from Du et al.[29] The lack of association in the study by Vilegas et al could be due to a smaller sample size and only using women.[32]

In the Kuopio Ischaemic Heart Disease Risk Factor study, a 35% reduced risk of DM was associated with the consumption of berries. The researchers suggested it could be due to the polyphenolic compounds present in berries.[33]

In African American women, researchers found two or more sweetened fruit drinks had a 31% increased risk of DM when compared to consuming less than one drink per month. Interestingly, orange juice and grapefruit juice were not associated with increased risk.[34] Research in postmenopausal women found one cup of juice was not associated with an increased risk of HTN or DM, but consuming three cups or more was associated with an increased risk of HTN.[35] The increased risk may be explained by potential weight gain from an excessive intake of calories, a known risk factor for HTN. The researchers recommend limiting juice to one cup daily to not increase DM risk, contradicting the findings of Palmer et al suggesting more than one fruit drink a month increases DM risk.[34,35]

A case-control study concluded individuals with a lower FV intake or higher intake of dark yellow vegetables had higher odds of prediabetes, but a high FV or high fruit intake had a lower odds ratio (OR) of prediabetes.[36] In overweight women, researchers found consumption of green leafy and dark yellow vegetables were associated with reduced DM risk but no other inverse associations were found.[37]

In female nurses, green leafy vegetables were associated with a lower DM hazard ratio, while juice had an increased risk.[38] The potential association of increased risk with juice aligns with previous studies suggesting juice should be limited.[34,35,38]

The Japanese Elderly Intervention Trial found as total vegetable intake increased, significant decreases were seen in HbA1C, triglyceride, and waist circumference. An intake of 200 grams or more vegetables and more than 70 grams of green vegetables correlated with improved HbA1C and triglyceride levels.[39] In another Japanese trial, no significant change in DM risk was observed with the consumption of fruits, vegetables, or FV.[40]

A case-cohort study found a 21% lower hazard ratio for DM with higher FV intake. The researchers also found a higher vegetable intake and higher variety of FV was associated with a reduced risk of DM.[41]

Four meta-analyses and two large studies combining multiple significant cohorts were examined. Muraki et al combined the Nurses' Health Study, Nurses' Health Study II, and the Health Professionals Follow-Up cohorts. Blueberries, grapes, and apples were significantly associated with a lower risk of DM, higher juice intake was associated with increased DM risk, and GI had no association.[31]

Wang et al examined 23 prospective cohort studies and found a higher intake of berries, green leafy vegetables, yellow vegetables, cruciferous vegetables, or their fiber to be associated with a lower risk of DM.[42]

Li et al concluded fruit or vegetable, not fruit and vegetable, intake decreased DM risk.[43] The researchers identified a 6% lower DM risk per one serving of fruit and 13% lower risk per 0.2 servings of green leafy vegetables.[43] Similarly, Wu et al found 2-3 vegetable servings daily and 2 servings daily of fruit resulted in a lower risk of DM. However, more than 5 FV servings daily was not associated with further decreases in DM risk.[44]

Chen et al combined a prospective cohort study and a meta-analysis. In the cohort study, green leafy vegetable and cruciferous vegetable intake did not find a significant association on DM risk. However, the meta-analysis found a slightly significant 9% decrease in DM risk with a high consumption of green leafy vegetables and a 13% decrease with a high consumption of cruciferous vegetables.[45]

The last analysis combined NIH-AARP and the EPIC-Elderly cohorts as part of the CHANCES study (Consortium on Health and Ageing Network of Cohorts in Europe and the United States). No significant association on DM risk was found.[46] This contrasted with results from other studies and could possibly be explained by the strong heterogeneity between the two large cohorts.

The role of phytonutrients from fruits and vegetables on diabetes

In a randomized control trial (RCT), researchers found an increase of beneficial nutrients in the blood circulation in the group that increased their FV consumption for 12 weeks versus the group that had low intake.[47] Another RCT in obese subjects found an increase in FV led to a higher carotenoid content resulting in a cardioprotective property of high-density lipoprotein expression.[48] In the TOSCA.IT study, Vitale et al found individuals with DM tended to have a lower pattern of polyphenol intake.[49] The same researchers then conducted another study and found a higher intake of polyphenols was associated with less inflammation and a better risk factor profile relevant to cardiovascular health.[50]

The EPIC-Norfolk study showed a FV diet was strongly inversely associated with incident DM. Higher levels of vitamin C, beta-carotene, and lutein each shared an inverse association with incident DM. Further, the researchers concluded DM odds were reduced by 40% per 70-80 grams FV serving.[51]

An NHANES study found a consumption of FV containing high levels of flavonoids resulted in lower levels of diabetes-related biomarkers in individuals with DM.[52]

Researchers found a reduction in DM from a higher intake of the quercetin and myricetin, flavonoids primarily found in apples. It was suggested an increased intake of apples could lead to a lower risk in various chronic diseases.[53]

A study of nondiabetic relatives of patients found an intake of alpha-carotene, beta-carotene, and lycopene had a beneficial association with glucose metabolism in men, but not women.[54] A similar study found only high levels of alpha and beta-carotene were associated with a lower DM risk.[55]

Montonen et al found vitamin E and cryptoxanthin were significantly associated with a reduced risk of DM, various tocopherols were inversely related to DM risk, and vitamin C demonstrated no association with risk.[56]

Gaps and limitations

Small study samples may not produce as reliable results as larger studies. However, smaller studies can provide insight for researchers to duplicate with larger samples to increase reliability. Studies with only one ethnicity, one race, and/or one sex work well when research is focused on the respective population. However, it may not be generalizable to other populations. This leaves a gap in the literature for FV on H/L individuals.

Measurement error can be a common concern in diet recall studies. Researchers can try to limit measurement error by using multiple, validated diet recall methods (e.g. 24-hr recall, food diary, FFQ). Altering the FFQ and self-administering the FFQ[40] can potentially increase measurement error. In one study, only one diet history was collected in 23 years of follow up. [56] After 4-7 years, diet history data can become unreliable.[8]

The Colón-Ramos et al study suffered from weak study design. The study methods include a two-question survey, low response rate, and a lack of a validated interview process for assessing FV intake.[9] Future studies with stronger study designs would be needed to support the findings.

Two meta-analyses[45,46] suffered from medium-high heterogeneity, meaning studies the researchers selected had above average differences in how the studies were designed and carried out. Heterogeneity can increase the difficulty of reaching meaningful conclusions.

Conclusions

As of 2019, there is not an absolute consensus on the role fruits, vegetables, or their derivatives on risk of type 2 diabetes. However, an ample amount of studies across multiple cohorts, study designs, and race/ethnicities seem to support the notion fruits and vegetables may reduce the risk of diabetes. Clearer conclusions could potentially be made if a universal FV classification was used and studies utilized strong study designs for collecting dietary recalls. More RCT's are recommended to see if specific fruits or phytochemicals have a significant association on diabetes risk factors. The current study is warranted to add additional data on colors of FV on US Hispanic/Latinos, a known gap in the literature.

Methods

Study design and recruitment

The HCHS/SOL is a multi-center, prospective cohort study of 5,740 self-identified H/L participants aged 18-74 years old. Individuals were enrolled between 2008-2011 in one of four field centers (Bronx, NY, Chicago, IL, Miami, FL, San Diego, CA) and included Mexican, Cuban, Puerto Rican, Dominican, Central American, and South American backgrounds. A stratified two-stage area probability sampling of household addresses was used for recruitment to reduce bias and ensure broad representation of the target population. The three steps of the recruitment protocol are initial mailings describing the study to sample addresses, contact by telephone if phone number is available, and in-person contacts. After contact is established and the individual agrees to participate, a screener will evaluate household members for eligibility. Individuals are ineligible if they plan to leave the testing area within 6 months, do not live at the address, active-duty military, or are not physically able to attend the clinic examination. If eligible, personal information, contact information, informed consent, and a medical release form were collected. The study design allows for flexibility to achieve study goals with minor disruption. Each site received Institutional Review Board (IRB) approval for this study.[57] This project was reviewed by the University of North Florida IRB and qualifies for a waiver of IRB review.

Data collection

Individuals participated in a questionnaire and a clinical examination. The questionnaire collects the following information from each individual: health and medical history, family history, acculturation, social and behavioral factors (e.g. association with groups/religion, HL values/traditions), occupation, access and use of health care, smoking history, alcohol consumption, physical activity, disabilities, weight gain/loss, sleep habits and disorders, medications/supplement use, oral health, two 24-hour dietary recalls (collected at baseline and six weeks after), hearing ability and noise exposure. The clinical examination collected blood pressure, pulmonary function, sleep assessment, electrocardiogram (ECG), weight, height, abdominal measurement, bioelectrical impedance, physical activity tracked by activity monitors worn by individuals, dental exam, audiometric testing, and cognitive function tests.[58]

Dietary assessment

Deidentified secondary data of the 5,740 individuals that completed both 24-hour recalls were analyzed. The recall used trained interviewers using a multiple-pass approach. The first pass uses the NDSR Quick List to collect the initial foods and beverages consumed by the participant in the previous day. The second pass reviews the Quick List for missing data and large gaps of time between meals. The third pass collects additional food and beverages not on the Quick List and collects more descriptive information about each food and beverage consumed. The fourth pass reviews all the food details collected to correct for any discrepancies or missing data. Weighed fruit and vegetable intakes were recorded for each participant by day for analysis.[59] Using the United States Department of Agriculture's (USDA) Food Patterns Equivalents Database: 2009-2010: Methodology and User Guide (FPED), FV were converted to one cup serving equivalents in grams. Each one cup equivalent was converted to a standard serving size. With two exceptions, a standard serving of a fruit or vegetable is defined as being a ½ cup. One cup is considered a serving for raw, leafy green vegetables and a ¼ cup is considered a serving for dried fruits. Each FV was identified and assigned to a color group. The color groups are green, yellow/orange, red/purple, white, and uncategorized. Figure 1 will show the FV included for each color group. FV criteria for excluded FV are as follows: serving size information from FPED or FDA data not available, mixed dishes (e.g. chicken and vegetable soup), beans, sauces, condiments, seasonings, jelly/jam, chips, and no weighed amount for food item provided by participant. Mixed fruits or vegetables, and derivatives of certain foods (e.g. French fries) were included in the uncategorized category. For food items lacking a FPED serving size, the US Food and Drug Administration (FDA) serving size was used to count as one serving (e.g. French fries). The average by color, day, and total were calculated for each individual.

Green	White	Yellow/Orange
Cooked spinach, turnip, collard, mustard, chard kale	Applesauce	Pineapple
Raw spinach, turnip, collard, mustard, chard, kale	Apples	Peaches, nectarines, clementines, tangelos
Green beans	Pears	Mango
Peas	Bananas	Papaya
Broccoli	Potatoes	Carrots
Lettuce salads	Plantains	Corn
Spinach or romaine salads	**Uncategorized**	Summer squash
Nopal	Dried fruit	Yams/Sweet Potatoes
Red/Purple	Melons	Mandarins
Grapes	Other fruit	Winter Squash
Strawberries	Other vegetables	Avocado
Grapefruit	Fries/Hashbrowns/Tater tots	
Tomato	Potato salad	
	Ketchup	
	Salsa	
	Pico de Gallo	
	Mixed vegetables	

Figure 1: fruits and vegetables included for each color group.

Statistical analysis

Descriptive data include sociodemographic characteristics of participants by total intake and level of fruit and vegetable intake (below versus above median), and intake of the different fruit and vegetable color groupings by ethnic background. Survey linear regressions were used to evaluate the association of intake levels of fruit and vegetable color groupings with cardiometabolic markers (BMI, HbA1C, glucose, post-OGTT, insulin, HDL, LDL, and triglycerides). Cardiometabolic markers were log-transformed due to skewed distributions. Survey logistic regression models were used to evaluate the association between intake levels of FV color groupings and DM using linear and logistic regression models were adjusted for age, sex, field center, ethnic background, smoking status, physical activity level, total energy intake, polyunsaturated fatty acids, trans fatty acids, and intake of whole grains, red and processed meat, and sugar-sweetened beverage. Furthermore, the final models were mutually adjusted by other coloring groups. For all analyses, survey-specific procedures were used to account for 2-stage sampling design, cluster sampling, and stratification. SAS 9.4 (SAS Institute, Cary, NC)

Results

A total of 5,740 participants were included in the analysis. Table 1 shows the sociodemographic characteristics of Hispanic and Latino adults by tertiles of fruit and vegetable intake (all: 0-36.7 servings per day, below median: 0-3.0 servings per day, above median: 3.1-36.7 servings per day). Consuming above the median of FV had a lower percentage of obese individuals (38.7%) versus below the median (42.2%). A higher percentage of participants with a higher education consumed more FV (43.6%) than high school (24.4%) and less than high school (31.9%) education levels. Higher FV intake had lower cigarette pack years (4.7 years) compared to the lower FV intake (6.0 years). Higher FV intake had a higher energy intake (2023.1 kcal/daily) versus a lower FV intake (1915 kcal/daily).

Table 1: Sociodemographic characteristics of Hispanic and Latino adults by tertiles of fruit and vegetable intake: HCHS/SOL, 2008-2011

	n	All (0-36.7 servings/day)	Below Median (0-3.0 servings/day)	Above Median (3.1-36.7 servings/day)
		n=5740	N=2823	N=2917
Age (y)		41.9±0.4	40.8±0.4	43.0±0.5
BMI (kg/m^2)		29.5±0.1	29.6±0.2	29.4±0.2
Gender, %				
Female	3564	55.2	54.9	55.6
Male	2176	44.8	45.1	44.4
Center, %				
Bronx	1373	27.7	29.9	25.4
Chicago	1370	14.8	15.7	14.0
Miami	1553	32.3	33.3	31.3
San Diego	1444	25.2	21.1	29.3
Yearly Household Income, %				
$10,000 or less	793	13.1	14.8	11.3
$10,001 - $20,000	1751	28.8	29.4	28.2
$20,001 - $40,000	1769	30.8	29.3	32.4
$40,001 - $75,000	708	13.2	12.6	13.8
$75,001 or more	229	5.1	3.7	6.4
Not reported	490	9.0	10.2	7.8
Education level, %				
Less than high school	2181	33.1	34.3	31.9
High School or equivalent	1400	26.4	28.4	24.4

>Higher school or equivalent	2147	40.3	37.1	43.6
Not reported	12	0.1	0.1	0.2
Background, %				
Dominican	497	10.2	9.2	11.2
Central American	598	7.7	8.7	6.7
Cuban	924	22.7	23.7	21.6
Mexican	2231	35.8	31.4	40.3
Puerto Rican	939	14.2	17.8	10.5
South American	384	5.0	4.4	5.7
Others/Mixed	167	4.5	4.8	4.1
Years Living in the U.S., %				
US born	972	21.4	25.8	16.9
Not US born but ≥10 years	4408	72.5	74.0	71.0
Not US born but <10 years	1310	27.5	26.0	29.0
Confirmed Diabetes*, %				
Yes	1030	13.6	13.1	14.0
No	4685	86.4	86.9	86.0
BMI, %				
<18.5 kg/m^2 (underweight)	34	0.9	0.9	0.9
18.5 - 24.9 kg/m^2 (healthy weight)	1082	21.2	22.1	20.3
25 - 29.9 kg/m^2 (overweight)	2154	37.4	34.8	40.1
≥30 kg/m^2 (obese)	2458	40.5	42.2	38.7
Cigarette pack years		5.3 ± 0.3	6.0±0.4	4.7±0.4
Energy intake (kcal/d)		1968.8 ± 11.5	1915.1±14.1	2023.1±16.1
PUFA (g/d)		15.4 ± 0.1	15.1±0.1	15.6±0.2
trans fatty acids (g/d)		2.7 ± 0.02	2.7±0.03	2.7±0.03
Whole grain (servings/d)		1.5 ± 0.04	1.4±0.05	1.6±0.06
Red and processed meat (servings/d)		1.04 ± 0.01	1.06±0.01	1.03±0.02
SSB's (servings/d)		1.8 ± 0.02	1.8±0.03	1.8±0.03
Physical activity level, %				
Inactive	1360	22.2	23.4	21.1
Low activity	769	12.1	12.3	12.0
Medium activity	629	10.6	10.9	10.4
High activity	2961	55.0	53.4	56.6

BMI, body mass index; PUFA, polyunsaturated fatty acids; SSB, sugar-sweetened beverage.
All data are presented as Mean ± SE or percentage. All analyses were weighted to adjust for sampling probability of selection and nonresponse.
*Fasting glucose, post OGTT glucose, and HbA1C were measured for diabetes. If participants were high on one or more, they were considered to have diabetes. (FPG≥126mg/dl; or OGTT≥200mg/dl; or HbA1C≥6.5%)

Table 2 shows the fruit and vegetable intake by color groups by the various H/L groups. Puerto Ricans consumed the lowest FV of all H/L groups. South Americans consumed the highest FV of all H/L groups. Across all groups, the red/purple FV were the least consumed.

Uncategorized FV were the most consumed across all groups. Excluding the uncategorized group, white FV had the highest consumption across all groups.

Table 2. Fruit and Vegetable intake by color groups by Hispanic/Latino heritage

	Servings/day (min, max)	Dominican	Central American	Cuban	Mexican	Puerto Rican	South American	Others /mixed	All
Green	0, 11.0	0.3±0.04	0.4±0.04	0.4±0.03	0.5±0.03	0.3±0.03	0.6±0.06	0.5±0.07	0.4±0.02
White	0, 14.6	1.5±0.1	0.9±0.06	0.9±0.06	0.9±0.05	0.8±0.05	1.1±0.09	0.9±0.2	1.0±0.03
Yellow/Orange	0, 11.6	0.4±0.05	0.4±0.04	0.3±0.03	0.6±0.03	0.2±0.02	0.5±0.05	0.3±0.09	0.4±0.02
Red/Purple	0, 12.2	0.1±0.02	0.2±0.02	0.2±0.02	0.2±0.02	0.1±0.01	0.3±0.04	0.2±0.04	0.2±0.01
Uncategorized	0, 22.9	1.5±0.2	1.4±0.08	1.8±0.1	1.8±0.07	1.4±0.07	2.0±0.2	1.5±0.2	1.7±0.05
All	0, 36.7	3.8±0.2	3.3±0.1	3.6±0.2	4.0±0.1	2.8±0.1	4.4±0.3	3.4±0.3	3.6±0.07

Table 3 shows the intake of fruit and vegetable color groups and cardiometabolic risk factors. The data compares below the median FV intake with above the median FV intake. The unadjusted model and adjusted model had a few significant findings. The adjusted model adjusted for age, gender, heritage, site, physical activity, smoking, total energy intake, polyunsaturated fatty acids, *trans* fatty acids, whole grains, red and processed meat, and sugar-sweetened beverages. In the All FV group, a higher FV intake is associated with a higher total cholesterol (p=.01), but the significance no longer remains after adjustment (p=.75). There was a significant association in both models in a higher intake of Red/Purple FV for lower BMI (p=.002), lower insulin levels (p=.01), and higher HDL levels (p=.02). In the unadjusted model, a higher intake of Yellow/Orange FV had significant associations with a higher post OGTT glucose (p=.05), higher total cholesterol (p=.009), and higher HDL levels (p=.0007). In the adjusted model, no significant associations were observed. In the unadjusted model, significant associations were found with a higher intake of White FV for a higher HbA1C (p=.003), higher post OGTT glucose (p=<.0001), higher total cholesterol (p=.0003), higher LDL (p=.046), and higher triglyceride levels (p=.0023). These associations were no longer significant in the adjusted model, except for a higher post-OGTT glucose (p=.04) and higher triglyceride levels (p=.02). In the uncategorized group, the unadjusted model showed significant associations related to a lower BMI (p=.0013), lower HbA1C levels (p=.0002), and lower glucose levels (p=.0004). Only BMI (p=.04) still had a significant association after adjusting.

Table 3. Intake of fruit and vegetable color groups and cardiometabolic risk factors in HCHS/SOL (2008-2011)

	Log-BMI (kg/m^2)	Log-HbA1c (%)	Log-glucose (mg/dL)	Log-post OGTT glucose (mg/dL)	Log-insulin (pmol/L)	Log-total cholesterol (mg/dL)	Log-HDL (mg/dL)	Log-LDL (mg/dL)	Log-TG (mg/dL)
All									
Unadjusted									
Below median	3.37±0.006	1.73±0.004	4.59±0.005	4.72±0.01	2.35±0.02	5.24±0.005	3.86±0.007	4.73±0.008	4.68±0.01
Above median	3.36±0.005	1.74±0.004	4.60±0.005	4.73±0.01	2.35±0.02	5.26±0.006	3.86±0.007	4.75±0.008	4.76±0.02
P-value	0.42	0.19	0.20	0.26	0.94	0.01	0.77	0.11	0.0006
Adjusted									
Below median	3.38±0.006	1.75±0.004	4.61±0.005	4.79±0.01	2.36±0.02	5.27±0.005	3.88±0.006	4.77±0.008	4.74±0.013
Above median	3.38±0.005	1.76±0.004	4.62±0.006	4.78±0.01	2.36±0.02	5.27±0.005	3.87±0.007	4.77±0.008	4.78±0.016
P-value	0.97	0.18	0.11	0.71	0.99	0.75	0.41	0.75	0.07
Green									
Unadjusted									
Below median	3.37±0.005	1.73±0.004	4.59±0.005	4.72±0.009	2.37±0.02	5.24±0.006	3.85±0.007	4.73±0.008	4.73±0.01
Above median	3.36±0.006	1.74±0.004	4.59±0.006	4.73±0.01	2.34±0.02	5.26±0.006	3.87±0.007	4.75±0.009	4.71±0.02
P-value	0.57	0.28	0.98	0.70	0.28	0.07	0.06	0.08	0.25
Adjusted									
Below median	3.38±0.005	1.75±0.004	4.61±0.005	4.78±0.009	2.37±0.02	5.27±0.005	3.87±0.006	4.76±0.008	4.77±0.01
Above median	3.37±0.005	1.76±0.004	4.62±0.006	4.78±0.01	2.35±0.02	5.28±0.006	3.88±0.006	4.78±0.008	4.75±0.01
P-value	0.74	0.34	0.60	0.83	0.50	0.11	0.66	0.07	0.40
Red/Purple									
Unadjusted									
Below median	3.37±0.005	1.74±0.003	4.60±0.005	4.72±0.008	2.37±0.02	5.25±0.005	3.85±0.006	4.75±0.007	4.72±0.01
Above median	3.34±0.008	1.73±0.004	4.59±0.006	4.72±0.01	2.30±0.03	5.25±0.008	3.87±0.01	4.74±0.01	4.71±0.02
P-value	0.0005	0.09	0.57	0.92	0.016	0.81	0.04	0.54	0.57
Adjusted									
Below median	3.38±0.005	1.76±0.003	4.61±0.005	4.78±0.008	2.38±0.02	5.27±0.004	3.87±0.005	4.77±0.006	4.77±0.01
Above median	3.36±0.008	1.75±0.004	4.61±0.006	4.78±0.01	2.30±0.03	5.27±0.007	3.89±0.009	4.76±0.01	4.74±0.02
P-value	0.002	0.11	0.98	0.91	0.01	0.84	0.02	0.33	0.25
Yellow/Orange									
Unadjusted									
Below median	3.37±0.005	1.73±0.004	4.60±0.005	4.71±0.009	2.36±0.02	5.24±0.005	3.84±0.006	4.74±0.008	4.71±0.01
Above median	3.36±0.007	1.74±0.004	4.59±0.006	4.74±0.01	2.34±0.02	5.26±0.006	3.88±0.008	4.76±0.009	4.73±0.02
P-value	0.18	0.11	0.47	0.05	0.53	0.009	0.0007	0.07	0.33
Adjusted									

Below median	3.38±0.005	1.75±0.003	4.62±0.005	4.79±0.009	2.37±0.02	5.27±0.005	3.87±0.006	4.77±0.007	4.77±0.01
Above median	3.37±0.006	1.76±0.004	4.61±0.006	4.78±0.01	2.35±0.02	5.27±0.006	3.88±0.008	4.77±0.009	4.75±0.02
P-value	0.13	0.80	0.26	0.62	0.61	0.85	0.17	0.83	0.59
White									
Unadjusted									
Below median	3.36±0.006	1.73±0.004	4.59±0.005	4.70±0.01	2.35±0.02	5.24±0.005	3.85±0.007	4.73±0.008	4.69±0.02
Above median	3.37±0.005	1.74±0.004	4.60±0.006	4.75±0.01	2.36±0.02	5.26±0.005	3.87±0.007	4.75±0.008	4.75±0.02
P-value	0.74	0.003	0.098	<0.0001	0.80	0.0003	0.073	0.046	0.0023
Adjusted									
Below median	3.37±0.005	1.75±0.004	4.61±0.005	4.77±0.01	2.36±0.02	5.27±0.005	3.88±0.007	4.77±0.008	4.74±0.01
Above median	3.38±0.005	1.76±0.003	4.62±0.006	4.80±0.01	2.36±0.02	5.28±0.005	3.87±0.007	4.77±0.008	4.79±0.02
P-value	0.64	0.28	0.52	0.04	0.87	0.21	0.52	0.70	0.02
Uncategorized									
Unadjusted									
Below median	3.38±0.005	1.74±0.005	4.61±0.006	4.73±0.01	2.36±0.02	5.24±0.005	3.86±0.007	4.74±0.007	4.71±0.02
Above median	3.35±0.006	1.72±0.003	4.58±0.005	4.71±0.01	2.35±0.02	5.25±0.006	3.85±0.007	4.75±0.009	4.73±0.02
P-value	0.0013	0.0002	0.0004	0.16	0.68	0.28	0.50	0.21	0.31
Adjusted									
Below median	3.38±0.005	1.76±0.004	4.62±0.006	4.79±0.01	2.37±0.02	5.27±0.005	3.87±0.007	4.76±0.007	4.76±0.01
Above median	3.37±0.005	1.75±0.003	4.61±0.005	4.78±0.01	2.35±0.02	5.28±0.006	3.87±0.007	4.77±0.008	4.77±0.02
P-value	0.04	0.09	0.06	0.40	0.45	0.43	0.82	0.47	0.79

Data presented as Mean ± SE. All dependent variables were log-transformed due to skewed distributions. All analyses were weighted to adjust for sampling probability of selection and nonresponse.
Adjusted model: adjusted for age, gender, heritage, site, physical activity, smoking, total energy intake, polyunsaturated fatty acids, *trans* fatty acids, whole grains, red and processed meat, sugar-sweetened beverage.

Table 4 shows the fruit and vegetable intake by color groupings on the odds of confirmed diabetes. Model 1 was used for green, red/purple, yellow/orange, white, uncategorized color groups and adjusted for age, gender, heritage, site, physical activity, smoking, total energy intake, polyunsaturated fatty acids, trans fatty acids, whole grains, red and processed meat, sugar-sweetened beverages, and mutually adjusted by other coloring groups. Model 2 was used for all FV group and adjusted for age, gender, heritage, site, physical activity, smoking, total energy intake, polyunsaturated fatty acids, *trans* fatty acids, whole grains, red and processed meat, sugar-sweetened beverages. Above the median intake of white FV had higher odds of confirmed diabetes than below the median intake (p=.0005 unadjusted, p=.03 model 1). Before adjustment, there was lower odds of confirmed diabetes by consuming above the median of uncategorized FV ($p<.0001$) but was no longer statistically significant in model 1 ($p=.25$). All other FV groups showed no statistical significance.

Table 4 Fruit and vegetable intake by color groupings on diabetes confirmation[1]

		Below Median Reference	Above Median OR (95% CI)	P-value
Green				
	Unadjusted	1.00	0.96 (0.79, 1.15)	0.96
	Model 1	1.00	0.97 (0.80, 1.19)	0.78
Red/Purple				
	Unadjusted	1.00	0.85 (0.69, 1.03)	0.09
	Model 1	1.00	0.86 (0.69, 1.06)	0.15
Yellow/Orange				
	Unadjusted	1.00	1.10 (0.90, 1.35)	0.36
	Model 1	1.00	0.96 (0.76, 1.22)	0.75
White				
	Unadjusted	1.00	1.37 (1.15, 1.64)	0.0005
	Model 1	1.00	1.25 (1.02, 1.53)	0.03
Uncategorized				
	Unadjusted	1.00	0.68 (0.56, 0.82)	<0.0001
	Model 1	1.00	0.88 (0.70, 1.10)	0.25
All				
	Unadjusted	1.00	1.08 (0.90, 1.30)	0.42
	Model 2	1.00	1.19 (0.96, 1.46)	0.11

[1]Fasting glucose, post OGTT glucose, and HbA1C were measured for diabetes. If participants were high on one or more, they were considered to have diabetes. (FPG≥126mg/dl; or OGTT≥200mg/dl; or A1C≥6.5%).

Model 1: adjusted for age, gender, heritage, site, physical activity, smoking, total energy intake, polyunsaturated fatty acids, *trans* fatty acids, whole grains, red and processed meat, sugar-sweetened beverage, and mutually adjusted by other coloring groups.

Model 2: adjusted for age, gender, heritage, site, physical activity, smoking, total energy intake, polyunsaturated fatty acids, *trans* fatty acids, whole grains, red and processed meat, sugar-sweetened beverage.

All analyses were weighted to adjust for sampling probability of selection and nonresponse.

Discussion

The primary objective of this thesis was to determine if specific colors of FVs have an association with DM risk in the US H/L population.

While red and purple FV were not shown to reduce DM risk, a higher intake was associated with biomarkers related to lower DM risk (lower BMI, lower insulin levels, higher HDL levels). Red and purple FV in this study included grapes, strawberries, grapefruit and tomatoes. Incorporating these fruits regularly in an individual's diet may be beneficial in the prevention of DM. Further research could examine if the whole fruits or the flavonoids/polyphenols could be responsible for the effects.

Consumption of white FV had higher odds of having DM. FV in the white group are applesauce, apples, pears, bananas, potatoes, and plantains. This was surprising as apples have been considered to lower risk of DM.[53] However, the increase in risk could be associated with other FV in the category. For example, white potatoes were shown in one study to increase DM risk.[8] In another study, white potatoes were excluded from the analysis.[38] White potatoes are generally considered healthy due to high levels of vitamins, minerals, and fiber. Further research needs to investigate potatoes to see if negative effects on DM risk are directly related to potato consumption. Excluding the uncategorized group, white FV were the highest consumed. The possible overconsumption of white FV may play a role in the higher risk. More research should examine individual white FV to identify if increased DM risk is related to a specific FV.

Our results further support the findings from Colón-Ramos et al. with Puerto Ricans consuming the lowest FVs compared to other US Hispanic groups.[9] It warrants further research to determine if factors such as socioeconomic status, food market availability, and education play a significant role in low Puerto Rican FV intake.

In our study, no significant associations were found between green FV and DM risk. This was surprising because other studies found green FV or green, leafy vegetables to lower the risk of DM.[6,8,28,38,39,42,43,45] However, other studies reached the same conclusion of green FV having no significant association on DM risk.[33,46]

The differences in results of our study and other studies can be attributed to different study methods used. For instance, our study population focused exclusively on the US H/L population. For each study in the review, researchers developed their own FV classification and how they wanted to collect dietary recall data. The differences in data collection could lead to researchers reaching different conclusions with similar data.

Strengths of the study were having a good sample size, the use of multiple centers across the US, adjustments for confounding factors, participants weighing their food, and a multiple-pass system for collecting dietary data. The main weakness of the study is measurement error. Datasets were missing weight data for some food items reported by the participants. Despite multiple reviews of the dataset, the possibility of errors in data entry persist. Our FV classification system is a potential weakness due to having a limited amount of FV for each color group. Further tailoring the FV categories to common cultural foods consumed by the H/L population can improve the color groups. If more of the uncategorized FV were added to their respective color groups, the results could be different. Different variants of some fruit FV exist (e.g. white grapefruit and purple carrots) but were not differentiated in the dietary recall. Some FV had to be excluded because the foods were mixed with other foods. It is not possible to identify what quantity of each food is in a mixed dish. A future study should consider having participants weigh foods separately for researchers to have more data to work with.

More research is needed to draw stronger conclusions in the US H/L population. It would be beneficial for multiple studies of varying designs to utilize a similar FV classification system to improve consistency. When fruits and vegetables are grouped in a variety of ways or no groupings exist, it allows for the potential of significantly different results among studies. A longitudinal study similar to NHANES or EPIC should be conducted in the US H/L population for further insights. While the HCHS/SOL study used a 115-item FFQ at a year follow up, an FFQ collected closer to the completion of both 24hr food recalls could have increased validity of the diet recalls. RCT studies are difficult to design for long-term diet and disease research due to cost and complication with long-term participant diet adherence. However, RCT studies could be useful in identifying if specific FV such as white potatoes have an effect on biomarkers associated with DM. RCT studies should further explore the effects of flavonoids and fiber to identify if there is an effect on DM risk factors.

Conclusion

While the consumption of FV have shown protective effects for chronic disease, it remains to be seen if specific fruit and vegetables colors have a significant effect on DM risk. More research is needed to confirm results. Our sample included nearly 6,000 participants but can expand in the future to include more individuals. It can also benefit from further examination of the fruits and vegetables in each color group to determine if the FV should be adjusted to better reflect foods consumed in H/L population. Future research should further examine the associations of white and red/purple FV on diabetes risk.

References

1. Hispanic/Latino Americans and Type 2 Diabetes. Centers for Disease Control and Prevention website. https://www.cdc.gov/diabetes/library/features/hispanic-diabetes.html. Published September 15, 2019. Accessed January 3, 2020.
2. Schneiderman N, Llabre M, Cowie CC, et al. Prevalence of diabetes among hispanics/latinos from diverse backgrounds: The Hispanic Community Health Study/Study of Latinos (HCHS/SOL). *Diabetes Care*. 2014;37(8):2233-2239. doi:10.2337/dc13-2939.
3. O'Brien MJ, Alos VA, Davey A, Bueno A, Whitaker RC. Acculturation and the prevalence of diabetes in US Latino Adults, National Health and Nutrition Examination Survey 2007-2010. *Prev Chronic Dis*. 2014;11:176. doi:10.5888/pcd11.140142.
4. Kaplan MS, Huguet N, Newsom JT, McFarland BH. The association between length of residence and obesity among Hispanic immigrants. *Am J Prev Med*. 2004;27(4):323-326. doi:10.1016/j.amepre.2004.07.005.
5. McCurley JL, Mills PJ, Roesch SC, et al. Chronic stress, inflammation, and glucose regulation in U.S. Hispanics from the HCHS/SOL Sociocultural Ancillary Study. *Psychophysiology*. 2015;52(8):1071-1079. doi: 10.1111/psyp.12430.
6. Jacobs S, Kroeger J, Schulze MB, et al. Dietary Patterns Derived by Reduced Rank Regression Are Inversely Associated with Type 2 Diabetes Risk across 5 Ethnic Groups in the Multiethnic Cohort. *Curr Dev Nutr*. 2017;1(5). doi:10.3945/cdn.117.000620
7. Adeva-Andany MM, Rañal-Muíño E, Vila-Altesor M, Fernández-Fernández C, Funcasta-Calderón R, Castro-Quintela E. Dietary habits contribute to define the risk of type 2 diabetes in humans. *Clin Nutr ESPEN*. 2019;34:8-17. doi:10.1016/j.clnesp.2019.08.002.
8. Montonen J, Järvinen R, Heliövaara M, Reunanen A, Aromaa A, Knekt P. Food consumption and the incidence of type II diabetes mellitus. *Eur J Clin Nutr*. 2005;59(3):441-448. doi:10.1038/sj.ejcn.1602094
9. Colón-Ramos U, Finney Rutten L, Moser R, Colón-Lopez V, Ortiz A, Yaroch A. The Association Between Fruit and Vegetable Intake, Knowledge of the Recommendations, and Health Information Seeking Within Adults in the U.S. Mainland and in Puerto Rico. *J Health Commun*. 2015;20(1):105-111. doi:10.0.4.56/10810730.2014.914607.
10. Akresh IR. Dietary Assimilation and Health among Hispanic Immigrants to the United States. *J Health Soc Behav*. 2007;48(4):404-417. doi:10.1177/002214650704800405
11. Jackson Behan K, Mbizo J, Johnston MA, Dumas M, Yates MC. Does Race Alter the Relationship Between HbA1c and Glucose in Type 2 Diabetes? *Clin Lab Sci*. 2014;27(2):89-96. https://www.ncbi.nlm.nih.gov/pubmed/25000651. Accessed January 4, 2020.
12. Weigensberg MJ, Cruz ML, Goran MI. Association between insulin sensitivity and post-glucose challenge plasma insulin values in overweight Latino youth. *Diabetes Care*. 2003;26(7):2094. doi:10.2337/diacare.26.7.2094.
13. Lorenzo C, Hazuda HP, Haffner SM. Insulin resistance and excess risk of diabetes in Mexican-Americans: the San Antonio Heart Study. *J Clin Endocrinol Metab*. 2012;97(3):793-799. doi:10.1210/jc.2011-2272.
14. Avilés-Santa ML, Pérez CM, Schneiderman N, et al. Detecting prediabetes among Hispanics/Latinos from diverse heritage groups: Does the test matter? Findings from the

Hispanic Community Health Study/Study of Latinos. *Prev Med (Baltim)*. 2017;95:110-118. doi:10.0.3.248/j.ypmed.2016.12.009.

15. Ahmed M, Munir S. Diabetes Mellitus; Significance Of HbA1c Determination In Patients. *Prof Med J*. 2015;22(8):1076-1079. https://login.dax.lib.unf.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=109169339&site=eds-live&scope=site. Accessed January 11, 2020.
16. Raper N, Perloff B, Ingwersen L, Steinfeldt L, Anand J. An overview of USDA's Dietary Intake Data System. *J Food Compos Anal*. 2004;17(3-4):545-555. doi:10.1016/j.jfca.2004.02.013.
17. Subar, A. F., Dodd, K. W., Guenther, P. M., Kipnis, V., Midthune, D., McDowell, M., Tooze, J. A., Freedman, L. S., & Krebs-Smith, S. M. The Food Propensity Questionnaire: Concept, Development, and Validation for Use as a Covariate in a Model to Estimate Usual Food Intake. *Journal of the American Dietetic Association*. 2006;(10):1556–1563. doi:10.0.3.248/j.jada.2006.07.002.
18. Margetts, B. M., & Pietinen, P. European Prospective Investigation into Cancer and Nutrition: validity studies on dietary assessment methods. *International Journal of Epidemiology*. 1997;26(1):S1-5. doi:10.1093/ije/26.suppl_1.S1.
19. Pennington, J. A. T., & Fisher, R. A. Classification of fruits and vegetables. *Journal of Food Composition and Analysis*. 2009;*22*:S23–S31. doi:10.1016/j.jfca.2008.11.012.
20. Mirmiran, P., Bahadoran, Z., Moslehi, N., Bastan, S., & Azizi, F. Colors of fruits and vegetables and 3-year changes of cardiometabolic risk factors in adults: Tehran lipid and glucose study. *European Journal of Clinical Nutrition*. 2015;*69*(11):1215–1219. doi:10.1038/ejcn.2015.49.
21. Cömert, E. D., Mogol, B. A., & Gökmen, V. Relationship between color and antioxidant capacity of fruits and vegetables. *Current Research in Food Science*. 2020;2:1–10. doi:10.1016/j.crfs.2019.11.001.
22. Vioquel, J., Weinbrenner, T., Castelló, A., Asensio, L., & de la Hera, M. G. Intake of Fruits and Vegetables in Relation to 10-year Weight Gain Among Spanish Adults. *Obesity*. 2008;16(3):664–670. doi:10.1038/oby.2007.12.
23. Leenders, M., Boshuizen, H., Ferrari, P., Siersema, P., Overvad, K., Tjønneland, A., Olsen, A., Boutron-Ruault, M.-C., Dossus, L., Dartois, L., Kaaks, R., Li, K., Boeing, H., Bergmann, M., Trichopoulou, A., Lagiou, P., Trichopoulos, D., Palli, D., Krogh, V., & Panico, S. Fruit and vegetable intake and cause-specific mortality in the EPIC study. *European Journal of Epidemiology*. 2014;*29*(9):639. doi:10.1007/s10654-014-9945-9.
24. Liu, M., Yu, H., Yuan, S., Song, Y., Tang, B., Cao, Z., Yang, X., Towne, S. D., & He, Q. Association between fruit and vegetable intake and the risk of hypertension among Chinese adults: a longitudinal study. *European Journal of Nutrition*. 2018;*57*(7):2639–2647. doi:10.1007/s00394-018-1687-0.
25. Hertog, M. G., Bueno-de-Mesquita, H. B., Fehily, A. M., Sweetnam, P. M., Elwood, P. C., & Kromhout, D. Fruit and vegetable consumption and cancer mortality in the Caerphilly Study. *Cancer Epidemiology, Biomarkers & Prevention*. 1996;5(9):673–677. https://cebp.aacrjournals.org/content/5/9/673. Accessed January 12, 2020.
26. Luo, W.-P., Fang, Y.-J., Lu, M.-S., Zhong, X., Chen, Y.-M., & Zhang, C.-X. High consumption of vegetable and fruit colour groups is inversely associated with the risk of colorectal cancer: a case-control study. *British Journal Of Nutrition*. 2015;113(7):1129–1138. doi:10.1017/S0007114515000331.

27. Lee, J., Shin, A., Oh, J. H., & Kim, J. Colors of vegetables and fruits and the risks of colorectal cancer. *World Journal Of Gastroenterology*. 2017;*23*(14):2527–2538. doi:10.3748/wjg.v23.i14.2527.
28. Hung, H.-C., Joshipura, K. J., Jiang, R., Hu, F. B., Hunter, D., Smith-Warner, S. A., Colditz, G. A., Rosner, B., Spiegelman, D., & Willett, W. C. Fruit and vegetable intake and risk of major chronic disease. *Journal Of The National Cancer Institute*. 2004;96(21):1577–1584. doi:10.1093/jnci/djh296.
29. Du, H., Li, L., Bennett, D., Guo, Y., Turnbull, I., Yang, L., Bragg, F., Bian, Z., Chen, Y., Chen, J., Millwood, I. Y., Sansome, S., Ma, L., Huang, Y., Zhang, N., Zheng, X., Sun, Q., Key, T. J., Collins, R., & Peto, R. Fresh fruit consumption in relation to incident diabetes and diabetic vascular complications: A 7-y prospective study of 0.5 million Chinese adults. *PLoS Medicine*. 2017;*14*(4):1–19. doi:10.1371/journal.pmed.1002279.
30. Alperet, D. J., Butler, L. M., Koh, W.-P., Yuan, J.-M., & van Dam, R. M. Influence of temperate, subtropical, and tropical fruit consumption on risk of type 2 diabetes in an Asian population. *American Journal Of Clinical Nutrition*. 2017;105(3):736-745. doi:10.3945/ajcn.116.147090.
31. Muraki, I., Imamura, F., Manson, J. E., Hu, F. B., Willett, W. C., Dam, R. M. van, & Sun, Q. Fruit consumption and risk of type 2 diabetes: results from three prospective longitudinal cohort studies. *BMJ.* 2013;*347*:f5001. doi: 10.1136/bmj.f5001.
32. Villegas, R., Shu, X. O., Gao, Y.-T., Yang, G., Elasy, T., Li, H., & Zheng, W. Vegetable but not fruit consumption reduces the risk of type 2 diabetes in Chinese women. *The Journal of Nutrition.* 2008;138(3):574. doi:10.1093/jn/138.3.574.
33. Mursu, J., Virtanen, J. K., Tuomainen, T.-P., Nurmi, T., & Voutilainen, S. Intake of fruit, berries, and vegetables and risk of type 2 diabetes in Finnish men: the Kuopio Ischaemic Heart Disease Risk Factor Study. *American Journal of Clinical Nutrition*. 2014;*99*(2):328–333. doi:10.3945/ajcn.113.069641.
34. Palmer, J. R., Boggs, D. A., Krishnan, S., Hu, F. B., Singer, M., & Rosenberg, L. Sugar-sweetened beverages and incidence of type 2 diabetes mellitus in African American women. *Archives of Internal Medicine*. 2008;*168*(14):1487–1492. doi:10.1001/archinte.168.14.1487.
35. Auerbach, B. J., Littman, A. J., Tinker, L., Larson, J., Krieger, J., Young, B., & Neuhouser, M. Associations of 100% fruit juice versus whole fruit with hypertension and diabetes risk in postmenopausal women: Results from the Women's Health Initiative. *Preventive Medicine*. 2017;105:212–218. doi:10.0.3.248/j.ypmed.2017.08.031.
36. Safabakhsh, M., Koohdani, F., Bagheri, F., Siassi, F., Khajehnasiri, F., & Sotoudeh, G. Fruit and vegetable intake and pre-diabetes: a case-control study. *European Journal of Nutrition*. 2018;57(8):2953–2962. doi:10.1007/s00394-017-1569-x.
37. Liu, S., Serdula, M., Janket, S., NR, C., HD, S., WC, W., JE, M., JE, B., Liu, S., Serdula, M., Janket, S.-J., Cook, N. R., Sesso, H. D., Willett, W. C., Manson, J. E., & Buring, J. E. A prospective study of fruit and vegetable intake and the risk of type 2 diabetes in women. *Diabetes Care*. 2004;27(12):2993–2996. doi:10.2337/diacare.27.12.2993.
38. Bazzano, L. A., Li, T. Y., Joshipura, K. J., & Hu, F. B. Intake of Fruit, Vegetables, and Fruit Juices and Risk of Diabetes in Women. *Diabetes Care*. 2008;31(7):1311. doi:10.2337/dc08-0080.
39. Takahashi, K., Kamada, C., Yoshimura, H., Okumura, R., Iimuro, S., Ohashi, Y., Araki, A., Umegaki, H., Sakurai, T., Yoshimura, Y., Ito, H., & Interventi, J. E. D. Effects of

total and green vegetable intakes on glycated hemoglobin A1c and triglycerides in elderly patients with type 2 diabetes mellitus: The Japanese Elderly Intervention Trial. *Geriatrics & Gerontology International*. 2011;12:50-58. doi:10.1111/j.1447-0594.2011.00812.x.

40. Kurotani, K., Nanri, A., Goto, A., Mizoue, T., Noda, M., Kato, M., Inoue, M., & Tsugane, S. Vegetable and fruit intake and risk of type 2 diabetes: Japan Public Health Center-based Prospective Study. *The British Journal Of Nutrition*. 2013;*109*(4):709–717. doi:10.1017/S0007114512001705.
41. Cooper, A. J., Sharp, S. J., Lentjes, M. A. H., Luben, R. N., Khaw, K.-T., Wareham, N. J., & Forouhi, N. G. A prospective study of the association between quantity and variety of fruit and vegetable intake and incident type 2 diabetes. *Diabetes Care*. 2012;35(6):1293. doi:10.2337/dc11-2388.
42. Wang, P.-Y., Fang, J.-C., Gao, Z.-H., Zhang, C., & Xie, S.-Y. Higher intake of fruits, vegetables or their fiber reduces the risk of type 2 diabetes: A meta-analysis. *Journal Of Diabetes Investigation*. 2016;*7*(1):56–69. doi:10.1111/jdi.12376.
43. Li, M., Fan, Y., Zhang, X., Hou, W., & Tang, Z. Fruit and vegetable intake and risk of type 2 diabetes mellitus: meta-analysis of prospective cohort studies. *BMJ Open*. 2014;4(11):1. doi: 10.1136/bmjopen-2014-005497.
44. Wu, Y., Zhang, D., Jiang, X., & Jiang, W. Fruit and vegetable consumption and risk of type 2 diabetes mellitus: A dose-response meta-analysis of prospective cohort studies. *Nutrition, Metabolism and Cardiovascular Diseases*. 2015;25(2):140–147. doi:10.0.3.248/j.numecd.2014.10.004.
45. Chen, G.-C., Koh, W.-P., Yuan, J.-M., Qin, L.-Q., & van Dam, R. M. Green leafy and cruciferous vegetable consumption and risk of type 2 diabetes: results from the Singapore Chinese Health Study and meta-analysis. *British Journal of Nutrition*. 2018;119(9):1057. doi: 10.1017/S0007114518000119.
46. Mamluk, L., O'Doherty, M. G., Orfanos, P., Saitakis, G., Woodside, J. V, Liao, L. M., Sinha, R., Boffetta, P., Trichopoulou, A., & Kee, F. Fruit and vegetable intake and risk of incident of type 2 diabetes: results from the consortium on health and ageing network of cohorts in Europe and the United States (CHANCES). *European Journal Of Clinical Nutrition*. 2017;71(1):83–91. doi:10.1038/ejcn.2016.143.
47. Duthie, S. J., Duthie, G. G., Russell, W. R., Kyle, J. A. M., Macdiarmid, J. I., Rungapamestry, V., Stephen, S., Megias-Baeza, C., Kaniewska, J. J., Shaw, L., Milne, L., Bremner, D., Ross, K., Morrice, P., Pirie, L. P., Horgan, G., & Bestwick, C. S. Effect of increasing fruit and vegetable intake by dietary intervention on nutritional biomarkers and attitudes to dietary change: a randomised trial. *European Journal of Nutrition*. 2018;57(5):1855–1872. doi: 10.1007/s00394-017-1469-0.
48. Daniels, J.-A., Mulligan, C., McCance, D., Woodside, J. V, Patterson, C., Young, I. S., & McEneny, J. A randomised controlled trial of increasing fruit and vegetable intake and how this influences the carotenoid concentration and activities of PON-1 and LCAT in HDL from subjects with type 2 diabetes. *Cardiovascular Diabetology*. 2014;13(1):2–17. doi:10.0.4.162/1475-2840-13-16.
49. Vitale, M., Masulli, M., Rivellese, A. A., Bonora, E., Cappellini, F., Nicolucci, A., Squatrito, S., Antenucci, D., Barrea, A., Bianchi, C., Bianchini, F., Fontana, L., Fornengo, P., Giorgino, F., Gnasso, A., Mannucci, E., Mazzotti, A., Nappo, R., Palena, A. P., & Pata, P. Dietary intake and major food sources of polyphenols in people with

type 2 diabetes: The TOSCA.IT Study. *European Journal of Nutrition*. 2018;57(2):679–688. doi:10.1007/s00394-016-1355-1.
50. Vitale, M., Vaccaro, O., Masulli, M., Bonora, E., Del Prato, S., Giorda, C. B., Nicolucci, A., Squatrito, S., Auciello, S., Babini, A. C., Bani, L., Buzzetti, R., Cannarsa, E., Cignarelli, M., Cigolini, M., Clemente, G., Cocozza, S., Corsi, L., D'Angelo, F., … Rivellese, A. A. Polyphenol intake and cardiovascular risk factors in a population with type 2 diabetes: The TOSCA.IT study. *Clinical Nutrition*. 2017;36(6):1686–1692. doi:10.0.3.248/j.clnu.2016.11.002.
51. Cooper, A. J. M., Sharp, S. J., Luben, R. N., Khaw, K.-T., Wareham, N. J., & Forouhi, N. G. The association between a biomarker score for fruit and vegetable intake and incident type 2 diabetes: the EPIC-Norfolk study. *European Journal of Clinical Nutrition*. 2015;69(4):449–454. doi:10.0.4.14/ejcn.2014.246.
52. Mahoney, S. E., & Loprinzi, P. D. Influence of flavonoid-rich fruit and vegetable intake on diabetic retinopathy and diabetes-related biomarkers. *Journal of Diabetes and Its Complications*. 2014;28(6):767–771. doi:10.0.3.248/j.jdiacomp.2014.06.011.
53. Knekt, P., Kumpulainen, J., Järvinen, R., Rissanen, H., Heliövaara, M., Reunanen, A., Hakulinen, T., & Aromaa, A. Flavonoid intake and risk of chronic diseases. *The American Journal of Clinical Nutrition*. 2002;76(3):560–568. doi:10.1093/ajcn/76.3.560.
54. Ylönen, K., Alfthan, G., Groop, L., Saloranta, C., Aro, A., & SM, V. Dietary intakes and plasma concentrations of carotenoids and tocopherols in relation to glucose metabolism in subjects at high risk of type 2 diabetes: the Botnia Dietary Study. *American Journal of Clinical Nutrition*. 2003;77(6):1434–1441. doi:10.1093/ajcn/77.6.1434.
55. Sluijs, I., Cadier, E., Beulens, J. W. J., van der A, D. L., Spijkerman, A. M. W., & van der Schouw, Y. T. Dietary intake of carotenoids and risk of type 2 diabetes. *Nutrition, Metabolism and Cardiovascular Diseases*. 2015;25(4):376–381. doi:10.0.3.248/j.numecd.2014.12.008.
56. Montonen, J., Knekt, P., Järvinen, R., & Reunanen, A. Dietary Antioxidant Intake and Risk of Type 2 Diabetes. *Diabetes Care*. 2004;27(2):362-366. doi:10.2337/diacare.27.2.362.
57. LaVange, L. M., Kalsbeek, W. D., Sorlie, P. D., Avilés-Santa, L. M., Kaplan, R. C., Barnhart, J., Liu, K., Giachello, A., Lee, D. J., Ryan, J., Criqui, M. H., & Elder, J. P. Sample Design and Cohort Selection in the Hispanic Community Health Study/Study of Latinos. *Annals of Epidemiology*. 2010;20(8):642–649. doi:10.1016/j.annepidem.2010.05.006.
58. Sorlie, P. D., Avilés-Santa, L. M., Wassertheil-Smoller, S., Kaplan, R. C., Daviglus, M. L., Giachello, A. L., Schneiderman, N., Raij, L., Talavera, G., Allison, M., LaVange, L., Chambless, L. E., & Heiss, G. Design and Implementation of the Hispanic Community Health Study/Study of Latinos. *Annals of Epidemiology*. 2010;20(8):629-641. doi:10.1016/j.annepidem.2010.03.015
59. Manuals. Hispanic Community Health Study / Study of Latinos., https://sites.cscc.unc.edu/hchs/manuals-forms. Accessed January 12, 2020.